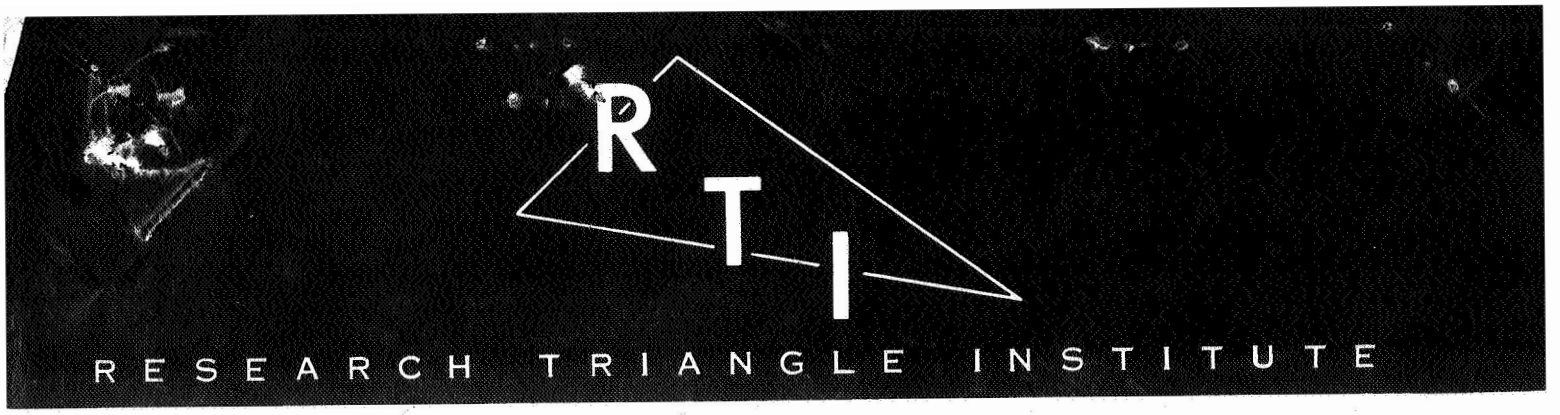

Engineering and Environmental Sciences Division
Research Triangle Institute
Post Office Box 12194
Research Triangle Park
North Carolina 27709

"Biomedical Applications Team"

Contract No. NSR-34-004-045
RTI No. EU-349

Quarterly Progress Report 3

15 December 1967 to 14 March 1968

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

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ABSTRACT

This third quarterly report covers the activities of the Research Triangle Institute's Biomedical Applications Team during the period from 15 December 1967 to 14 March 1968. The work reported here has been supported by NASA Contract No. NSR-34-004-045. This work was directed by Dr. J. N. Brown and has been under the general supervision of Dr. R. M. Burger, Director, Engineering and Environmental Sciences Division, Research Triangle Institute. The Biomedical Applications Team consists of RTI staff members, Dr. J. N. Brown, Group Leader; Mr. Ernest Harrison, Engineer; and Mr. R. L. Beadles, Engineer. During the preceding quarter considerable assistance in specific technological areas was obtained from Dr. Lee S. Miller, Engineer, and Mr. J. B. Tommerdahl, Engineer, also of the Engineering and Environmental Sciences Division. Medical research consultants to this program are Dr. E. A. Johnson, Professor of Cardiac Pharmacology, Duke University Medical Center, Durham, North Carolina; Dr. M. K. Berkut, Professor of Biochemistry, the Medical School of the University of North Carolina, Chapel Hill, North Carolina, and Dr. George Malindzak, Wake Forest University, Bowman-Gray School of Medicine, Winston-Salem, North Carolina. During the preceding quarter, the RTI Biomedical Applications Team has been active with the three medical institutions referred to in the preceding and, in addition, the Dental School of the University of North Carolina at Chapel Hill, North Carolina State University at Raleigh, N. C., and the Hospital for Special Surgery in New York, N. Y.

1.0 INTRODUCTION

This report documents the activities of the Biomedical Applications Team at the Research Triangle Institute, Research Triangle Park, North Carolina, for the period 15 December 1967 to 14 March 1968. This Biomedical Applications Team represents one part of the overall Technology Utilization Program of the National Aeronautics and Space Administration. The team has as its objective the transfer of NASA-generated technology into the fields of biological and medical research. This transfer of technology is accomplished primarily by matching problems existing in biological and medical research programs with technology developed in the nation's aerospace research and development programs.

The results of the activities of the Biomedical Applications Team can be summarized briefly as follows: 6 transfers of technology have been accomplished; 15 potential technology transfers have been identified; 4 demonstrations and presentations on NASA technology have been presented; 6 new biomedical problem abstracts have been prepared and submitted to NASA; 8 new information searches have been initiated; and 24 new technology-related problems in the medical field have been identified. Additional progress has been made in the attempt to understand more fully the technology transfer process and to improve the overall effectiveness of the biomedical applications program.

This report contains a brief summary of completed transfers of technology and a discussion of those potential transfers which are most likely to come to fruition. The report also contains a discussion of methods by which the overall effectiveness of the Biomedical Applications Team can be increased. The status of information searches, biomedical problem abstracts, computer evaluation reports, and bibliography are contained in the Appendices. The following section reviews briefly the objectives and operation of the NASA Biomedical Applications Team.

2.0 PROGRAM OBJECTIVES

The Technology Utilization Division of the National Aeronautics and Space Administration is making very significant efforts to transfer the scientific and technological results of the nation's aerospace activities to problems and needs existing in industrial, educational, medical and service institutions and organizations. There are many examples of success in the technology utilization program.* At present, the transfer of science and technology to the biomedical field is becoming one of the most important activities within this broad technology utilization program. There are, however, some rather unique problems associated with technology transfer in this particular field. Many of these problems are related to the differences in languages and methodologies of the physical and life sciences.

To facilitate the transfer of scientific and technological information to clinicians and medical researchers, NASA supports three multidisciplinary Biomedical Applications Teams. The primary objectives of the applications teams are: (1) to identify problems and needs existing in the medical field which appear to be "solvable" by the application of aerospace science and technology, (2) to identify the specific technologies or concepts which may lead to solutions of these problems, and (3) to document these transfers of science and technology so as to achieve maximum utilization of the results of the program. A further objective of this program is to contribute to an increased understanding of the elements involved in the information and technology transfer process, in order to perform the transfer process more efficiently and effectively. This understanding is primarily gained as a result of the identification of difficulties which impede transfer efforts in specific practical biomedical problems and the observation of those elements which contribute to efficiency and speed in the transfer process. The teams are to apply this increased understanding of the transfer process to their field operations so as to provide a more effective interface and information channel between the life sciences and the physical sciences.

To achieve these objectives, members of the applications team discuss with researchers and clinicians, at the participating medical institutions, problems that are being encountered in biological and medical research. These meetings and discussions are coordinated and, to a great extent, given direction and purpose by consultants who are staff members at the same institutions. The team seeks to

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* Technology Utilization Program Review presented by The Office of Technology Utilization, Office of Organization and Management, February 14, 1967.

understand fully both the nature of the problems and how they affect the progress of research or hinder patient treatment and care. Following these discussions, the team members specifically identify each discrete problem and translate these problems into the terminology of engineering and the physical sciences. When appropriate, a biomedical problem abstract, a concise statement of the problem, is prepared and disseminated through the Technology Utilization Division of NASA to the NASA centers and other participating organizations in the space program to uncover information pertinent to a solution. At the same time, the team employs the services of NASA Regional Dissemination Centers, such as the Science and Technology Research Center located adjacent to the Research Triangle Institute, to search the computerized aerospace information bank maintained by NASA. All information obtained from information searches, biomedical problem abstracts, or the experience of applications team members and consultants is then evaluated. In addition to the team members, the medical consultants plus the researchers and clinicians who originated the problems contribute to the evaluation process. Finally, the Biomedical Applications Team encourages and, when possible, aids researchers in the application or adaption of technology identified by these activities.

The following sections present discussions of the activities of the RTI Biomedical Applications Team during this quarter. These discussions include documentation of completed and potential technology transfers and evaluation of methods to increase the effectiveness of the biomedical applications program.

3.0 REVIEW OF TEAM ACTIVITIES

3.1 Problem Summaries

3.1.1 General

The activities of the Biomedical Applications Team related to specific problems during the quarter are discussed in the following paragraphs. The problems at each University are discussed separately. To document the publications given to researchers on the various problems, a bibliography of all documents disseminated by the Biomedical Applications Team is included as Appendix D. The documents are grouped in the appendix by problem number.

3.1.2 Duke University Medical Center

DU-1 Techniques for Calculating Left Ventricular Volume from Biplane Cineradiographs

The significance of this problem and a general description of the problem are contained in biomedical problem abstract DU-1.* The medical investigator originally involved in this activity was Dr. H. D. McIntosh, Chief, Cardiology Division, Duke University Medical Center. Dr. McIntosh's work is primarily concerned with adult heart disease. More recently, the applications team has become involved with a similar program under the direction of Dr. M. S. Spach, Chief, Pediatric Cardiology Division, Duke University Medical Center. As a result of discussions with both research groups at Duke University, we have been able to define the technological aspects of this problem more completely and precisely.

Briefly, the technique presently employed in obtaining left-ventricular volume as a function of time is as follows. First, a radiopaque material is injected into the blood stream entering the left ventricle so that the left ventricle will be visible in a radiographic image. Orthogonal views of the heart are obtained using biplane cineangiocardiographic techniques. The frame rate of the systems at Duke University is 60/second. The sequence of pictures recorded covers a time span of from 3-6 seconds. Thus, several hundred images of the heart must be processed for each patient. The specific steps involved in analyzing these data are as follows. First, a physician must identify in each frame of both orthogonal series of pictures the inside contour of the left ventricle. Following this, a technician must determine the maximum chord of each contour and measure the width of the contour at equal intervals along the maximum chord. The third step involves calculating volume from the data acquired in the preceding step. This calculation of volume is based upon the assumption that the left ventricle is approximately ellipsoidal in shape

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*Quarterly Progress Report No. 2, Contract No. NSR-34-004-035, RTI No. EU-279, "Biomedical Applications of NASA Science and Technology"

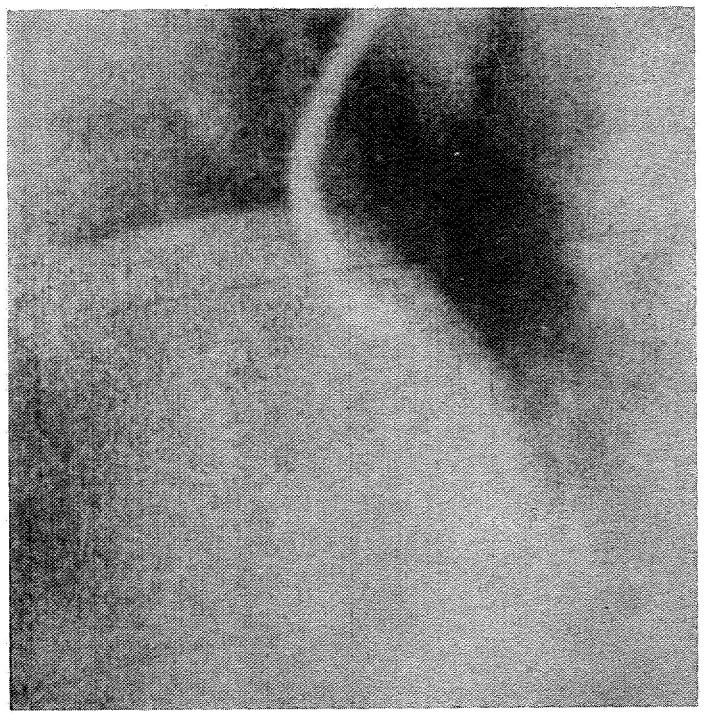
throughout the cardiac cycle. This process generally requires as much as two weeks per patient, and, as a result, progress of research is relatively slow. Additionally, the technique as a diagnostic tool is severely limited.

Initially, our statement of the problem indicated that what is needed is an automatic method for obtaining volume as a function of time from biplane cineangiocardiographs. Having investigated this procedure for a number of months, we felt that a more fruitful approach is to subdivide this general problem into three more specific requirements. Solutions to each of these three problems will significantly reduce the time required for analyzing this data. The three technological problems involved are: (1) a technique for improving image quality in the vicinity of the ventricular wall is needed to aid the physician in identifying the inside contour; (2) when the inside contour of the left ventricle is identified, a means for quantifying this contour and automatically determining the maximum chord and area is needed; (3) when solutions to (1) and (2) are obtained, it is highly desirable that the entire process of data identification, acquisition and processing be automated to the extent feasible. With complete automation of the process, this technique for assessing left ventricular function in the human heart can be an extremely effective clinical diagnostic tool.

Information related to solutions of these three problems has come from a very large number of different sources. Three computer searches of the NASA information system have been made: Analog-to-Digital to Topological Data, Bibliography No. 687; Pressure-Volume Measurement in the Heart, Bibliography No. 686; and Image Processing, Bibliography No. 817. All three searches were performed by the Science and Technology Research Center. A search of the files at the Scientific Information Exchange and a bibliography compiled by Mr. Robert Selzer at the Jet Propulsion Laboratory have also been very valuable. All of the references listed in Appendix D under Problem DU-1 were obtained either from these five sources or from references obtained from reports or articles cited in these five sources. In addition to information obtained as the result of literature searches, a number of individuals have been extremely helpful in obtaining a solution to this problem. Dr. Robert Nathan and Mr. Selzer at JPL, as well as Mr. Fennaughty, president of Information International Incorporated in Los Angeles,have been very helpful in discussing general approaches to accomplishing the needed data acquisition and processing. Progress which has been made with respect to the three requirements discussed in the preceding is outlined in the following paragraphs.

The identification of the inside contour of the left ventricle can be significantly aided by the application of digital image enhancement techniques similar to those used at the Jet Propulsion Laboratory in enhancing the lunar photographs. Mr. Selzer has been very helpful in demonstrating that these image enhancement techniques can be helpful in this task. Figure 1 illustrates the result of simple contrast enhancement of a radiographic image of the heart. As can be seen from the figure, simple contrast enhancement can be of significant value. By combining contrast enhancement with high frequency emphasis, the images can be improved to a greater extent. It is felt that the techniques proposed by Gabor will be of great value in this type of image enhancement. Specifically, Gabor has proposed that high frequency emphasis be applied along directions of an image normal to edges and that low pass filtering be applied along the direction of the contours. The employment of digital image processing using either flying-spot scanners or television type scanners on line with a small general purpose computer permits these techniques to be applied automatically. An alternative approach to facilitate the identification of ventricular contours was suggested by Mr. L. C. Crouch, Chief of the Reconnaissance Data Acquisition Storage and Retrieval Section, Wright-Patterson Air Force Base. Mr. Crouch indicated that since the ventricle wall occupies different positions in adjacent frames of the cineradiographs, then techniques for detecting moving objects in photographic images can be applied. The two techniques suggested are (1) use of a stereoscopic viewer to look at two adjacent frames as illustrated in Figure 2, and (2) the flicker technique - i.e., to display alternately two adjacent frames from the cineradiograph at a rate of 10-20 per second using either a television monitor or optical system. These techniques are presently being investigated to determine if they can significantly facilitate the process of contour identification.

Use of digital image processing leads very naturally to automatic acquisition of quantitative data, such as maximum chord and area of the contour. This can be accomplished in the following manner. The image is first scanned using a flying spot scanner, and sampled values of optical density are fed into a digital computer for processing. The data is processed to enhance general image quality and contours and then displayed on a high resolution television monitor. Using a fiber optics light pen, the physician then outlines the inside contour of the left ventricle. The coordinates of the contour are automatically stored in the digital computer. By further processing, the computer calculates maximum chord and area directly from the coordinates of the contour as identified by the physician. Once these parameters are obtained for each frame of the biplane cineradiographs, volume as a function of time can be calculated and displayed either graphically on the monitor or printed out from the computer in numerical or graphic form.



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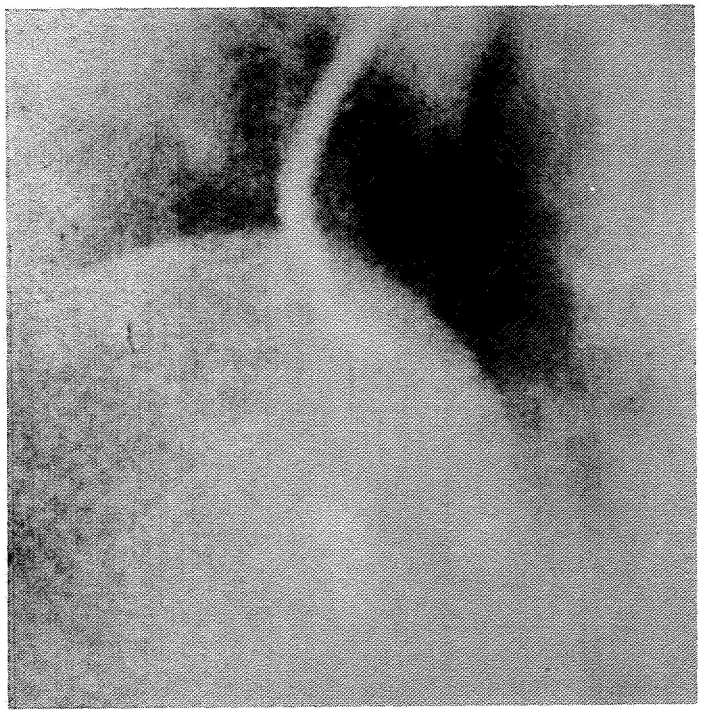


CONTRAST ENHANCEMENT

Fig. 1. Contrast enhancement in left ventricular contour.

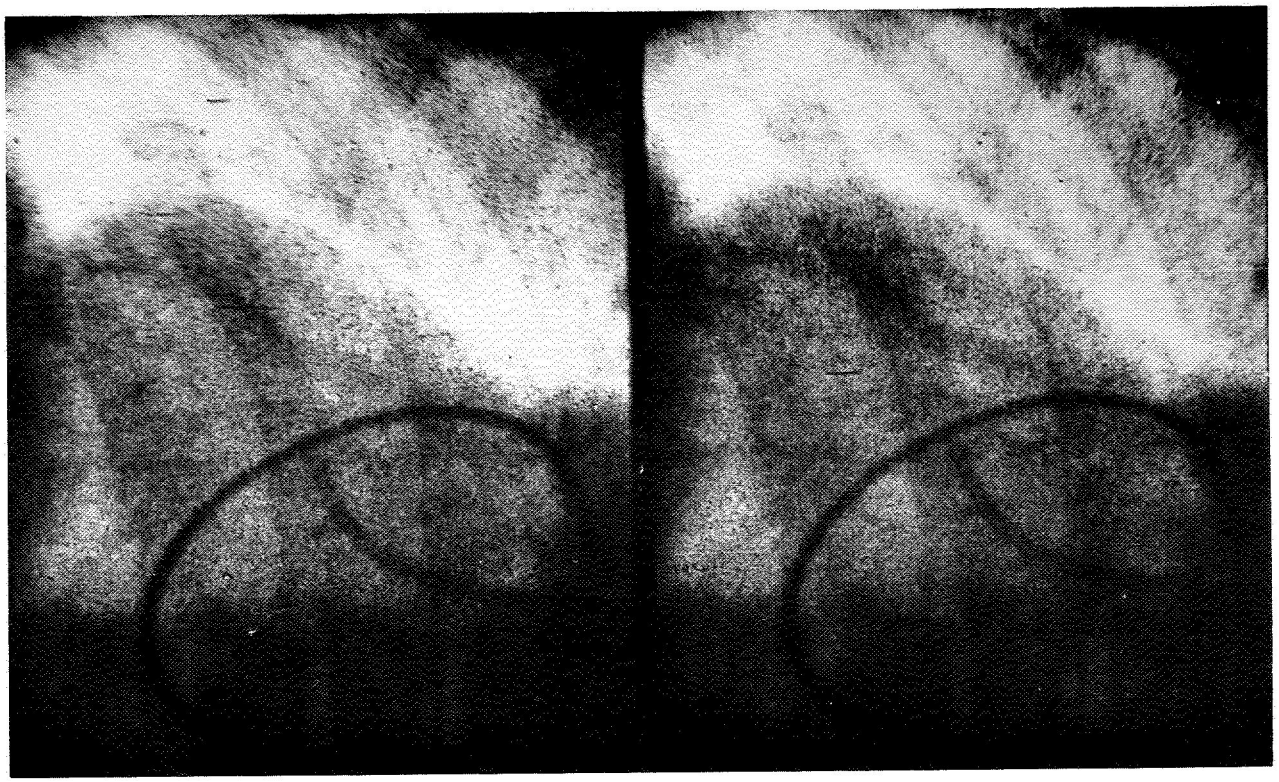


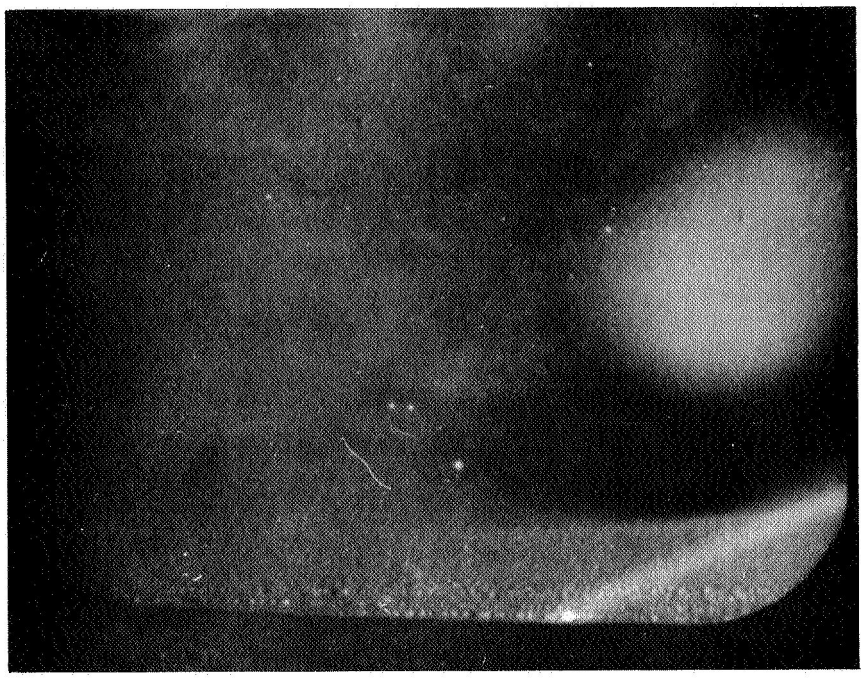
Fig. 2. Cineradiograph of the heart -- two adjacent frames.

The final step is to automate, to the extent feasible, the entire process of analyzing the cineradiographs. Sufficient information has been obtained at this time to state that it is feasible to automate this process in the following manner. The physician proceeds exactly as described in the preceding paragraph to outline the inside contour of the left ventricle using a light pen for the first frame of each of the two biplane cineradiographs. Image enhancement is used to help identify this contour as discussed in the preceding. He must only perform this function for the first frame of each of the two sequences of images. At this point, the digital computer takes control and uses the contour identified in the first frame as an approximation to the location of the contour in the second frame. Knowing that the contour changes only slightly from one frame to the next and knowing how optical densities vary along different regions of the contour, the computer can be programmed to search for the new contour location in a very logical manner. Once the ventricular contour is located in the second frame, this information is used as an approximation in the third frame and so on through the whole sequence. By this application of digital image processing (both enhancement and analysis), the time required to completely process data for one patient can be reduced from approximately two weeks to hopefully no more than one hour.

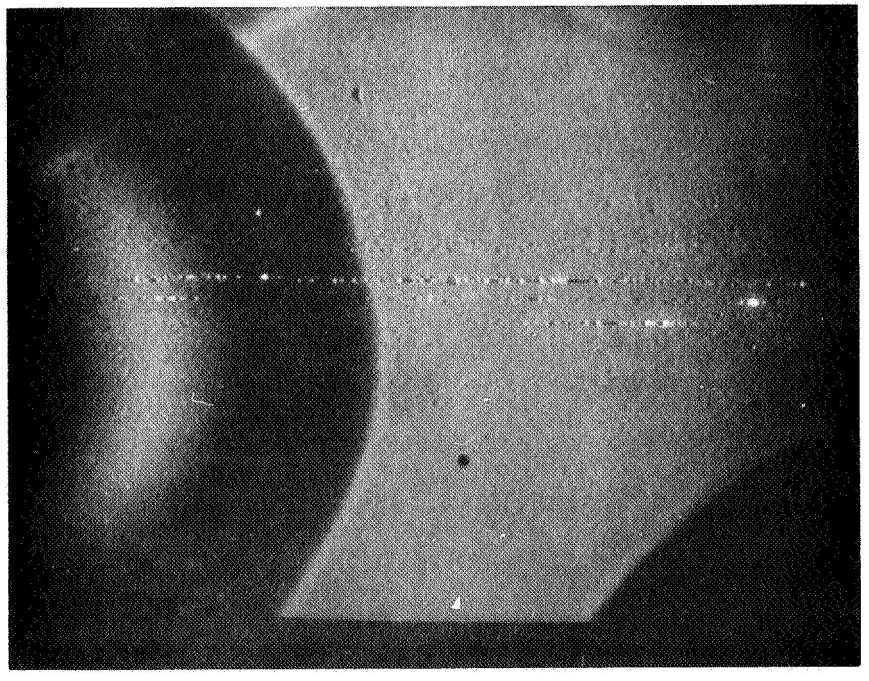
It is stressed that the above approach to this problem is technologically feasible. The remaining problem is one of obtaining the necessary equipment, which can cost as much as $500,000 depending upon system specifications. A very significant effort at Duke University has been expended in the preparation of a grant application for obtaining the necessary equipment and performing the necessary computer program development to accomplish the operations described in the preceding paragraphs.

DU-6 Correction for Latency in Vidicons

A successful transfer of technology has been accomplished and reported for this problem. No further progress has occurred or in fact was necessary. Recently, however, pictures were obtained which demonstrate very clearly the improvement in image quality when stroboscopic lighting is used with television monitoring of microscopic tissue specimens. These pictures, illustrated in Figure 3, are video tape recordings of small bubbles moving rapidly across the field of view of an optical microscope. Air bubbles demonstrate more clearly the effect of stroboscopic lighting as compared to continuous lighting than do images of more complex structures such as cardiac tissue.



CONTINUOUS LIGHTING



STROBOSCOPIC LIGHTING

Fig. 3. Optical micrographs of moving air bubbles.

DU-8 Methods of Quantitatively Studying Diseased Membranes in Joints of the Human Body

Activities related to this problem are discussed in Section 3.2, Presentations and Demonstrations.

DU-9 4-Channel Telemetry System for Experimental Work with Dogs

Recent information obtained from Ames Research Center, Tech Brief 68-10065, indicates that design work on a multi-channel telemetry system has been completed. This circuit development work has been in progress by Mr. Tom Fryer at Ames for approximately eight months, and it has been anticipated that the result would be applicable to this problem. Technical information has been forwarded to Dr. Andrew H. Wallace at Duke University, and it appears that the Ames system will accomplish the required function. At the present time an attempt is being made to determine the optimum manner for obtaining units for this work.

DU-10 Techniques for Monitoring Heart Rate, Rapid Changes in Blood Pressure, and Detecting Arrhythmias Directly and Automatically from Physiological Data

This particular problem represents in fact a number of specific problems related to monitoring patients in cardiac intensive care units. After an initial investigation, it was decided that meaningful solutions would come in the form of sound engineering and that searches for new technologies would not be extremely fruitful. However, as a result of periodically reviewing all problems which are encountered in this program and continually attempting to relate these problems to new technology, it was possible to suggest a unique approach in the area of patient monitoring within the context of this problem.

The specific problem referred to here relates more to research than to patient monitoring at the present time. Specifically, it is the opinion of medical investigators that changes in electrocardiographic (EKG) signals precede the onset of cardiac failure by a significant period of time. It would be very valuable to be able to study these EKG signals immediately prior to the onset of cardiac failure. The problem is that it is not feasible to record these signals on tape continuously for a large number of patients as would be required for such a study. At present the approach which is feasible is to use an endless magnetic tape which monitors one patient and stores past EKG signals for a specific interval of time. When a cardiac failure occurs, the tape transport is stopped, and the EKG preceding the failure is recovered. Equipment to accomplish this however is quite expensive. As a result, a large number

of these units is not available, and progress of research is relatively slow. Additionally, the stored information represents only a relatively short period of time preceding the failure.

During a recent visit to the Manned Spacecraft Center, discussions with Dr. Edward Moseley of the Medical Operations Research Branch indicated that EKG signals can be stored in very compact form using what is called a contourograph. The output of this instrument is a series of single EKG complexes recorded on light-sensitive paper. For each complex, time proceeds from left to right horizontally on the record, and successive complexes are displaced vertically downward on the record. This gives in essence a two-dimensional image with time increasing at different rates both from left to right and top to bottom. This technique of data compression was discussed with Dr. Wallace at the Duke University Medical Center, and it was learned that he was quite familiar with the technique but had not considered it because it is extremely difficult to obtain quantitative information. If, however, the attempt to establish a digital image processing center in the area is successful, it will be possible to extract quantitative data from contourograms very rapidly and to process and display the results in almost any desirable manner. Thus, this represents a potential improvement in presently used techniques of research involving continuous patient monitoring.

DU-11 Pressure Transducers for Intra-Cavitary or Subcutaneous Implantation in the Body and DU-31 Catheter-Mounted Pressure Transducers

During the preceding quarter a survey of manufacturers of fiber optics has been made to determine if the bundle of fibers required for the Ames optical pressure transducer can be purchased. It has been found that Dolan-Jenner Industries can supply the configuration needed for this device. The Applications Team has also investigated methods of fabricating the necessary bundle configuration using the new optical fibers obtained from Langley Research Center. During the next quarter one or two prototype transducers will be fabricated using the diaphrams obtained from Ames, and evaluation of these units will be initiated at Duke University Medical Center and the Medical School at the University of North Carolina.

DU-23 Methods of Improving Resolution and General Quality of Electron Micrographs to Obtain more Information on the Structure of Cell Membranes

Initial discussions with Dr. J. R. Sommer, Department of Pathology, Duke University Medical Center, were directed toward the specific problem of how to improve electron micrographs of cell membranes in order to make their structure

more clearly visible. In subsequent discussions, however, the Applications Team has directed its efforts on a broader and, at the same time, more specific basis. A number of limitations of the electron microscope impose limitations upon the progress of biological research involving this instrument. Some of these problems and the solutions which can be realized by the application of digital image processing are discussed in the following paragraphs.

A number of projects at the Duke University Medical Center have reached impasses due to limitations in electron microscopy. Physical limitations on the electron microscope include spherical aberration, astigmatism, and specimen contamination. The primary effects of these factors in an electron micrograph are: (1) reduced resolution as compared to the theoretical resolution obtainable with the electron microscope, (2) severe distortion and blurring of tissue structure, and (3) poor image contrast. Another significant problem is that staining of tissue is required to obtain a usable image of tissue structure; i.e., a material that is "electron dense" such as the heavy metals must be added to the specimen. Frequently, the result of this staining process is severe damage to the tissue structure which is being studied. A related problem which is inherent in any imaging system used for the study of biological tissue is that enormous amounts of time are devoted to analyzing the resulting electron micrographs. More specifically, what is referred to here is the need for an automatic method for cell counting, obtaining cell diameter or length distributions and other quantitative studies such as chromosome karotyping. Thus, problems in biological electron microscopy can be subdivided into three areas: (1) enhancement of the electron micrograph to allow visualization of latent information; (2) processing of the electron micrograph to allow an investigation of the effects of staining and to allow the use of either no stain or "weaker" stains; and (3) quantitative analyses of electron micrographs. Note that the operations performed on electron micrographs in (2) above are very similar to those which would be used in satisfying the requirements of (1). However, the images of specimen which have been subjected to light staining or no staining at all will be very faint and noisy as compared to those referred to in problem (1). Therefore, although the conceptual approaches may be quite similar in these two cases, the extent of processing and the quality of the result will be quite different. It is certain that the interpretation of the results of processing will be quite different in these two cases.

A significant number of reports and articles relevant to the three problem areas discussed in the preceding have been obtained as a result of Search No. 817, Image Processing, performed by the Science and Technology Research Center and a search on Image Processing obtained from the Scientific Information Exchange.

Dr. Robert Nathan and Mr. Robert Selzer of the Jet Propulsion Laboratory have again been extremely helpful in this area. As a result of the information gathered on image processing as it relates to electron microscopy, a grant application has been prepared and submitted for support for a program to apply these techniques in electron microscopy. (This is the same grant application referred to in the discussion of Problem DU-1. The research proposed in that application is directed toward both ventricular volume studies and processing of electron micrographs.) The proposed program will initially be directed toward five specific investigative areas of physiological research. These areas are: (1) study of the contractile process in cardiac muscle, (2) studies of the development of cardiac tissue, (3) studies of junctional membrane complexes, (4) studies of structural periodicity in a number of different kinds of tissue, and (5) cytochemistry.

DU-25 A Signal-Conditioning and Multiplexing System for Multiple Electrode EKG Patient Monitoring

As pointed out in previous reports, many of the hybrid circuit designs at Ames Research Center can be of value in a variety of signal conditioning systems in both medical research and patient monitoring. At present, however, the cost of obtaining small numbers of such circuits is prohibitive. Therefore, the Biomedical Applications Team, in order to be of immediate aid, arranged discussions between physicians at Duke University and instrumentation engineers at the Research Triangle Institute to discuss specific instrumentation requirements. As a result, the Research Triangle Institute is presently designing and fabricating, using "conventional integrated circuit" techniques, four special-purpose, multi-channel, signal-conditioning systems for the Duke University Medical Center. Because of the fact that these four systems are to be used as research tools and are special purpose instruments, it was felt that this was the best approach. It has been possible for the system design engineer, Mr. J. B. Tommerdahl, of the Engineering and Environmental Sciences Division of RTI to continually discuss the particular applications throughout the design and fabrication of these units. At present, one of these units, a 7-channel high-impedance amplifying system, has been completed and is functioning at the Duke University Medical Center. A photograph of the amplifier section of this unit is illustrated in Figure 4.

DU-26 Cardiac Artery Constrictor

This problem has been discussed in a previous report.* The artery constrictor which has been used in the past is illustrated in Figure 5-a. The constrictor consists

* Quarterly Progress Report No. 2, Contract No. NSR-34-004-045, RTI No. EU-349 "Biomedical Applications Team"

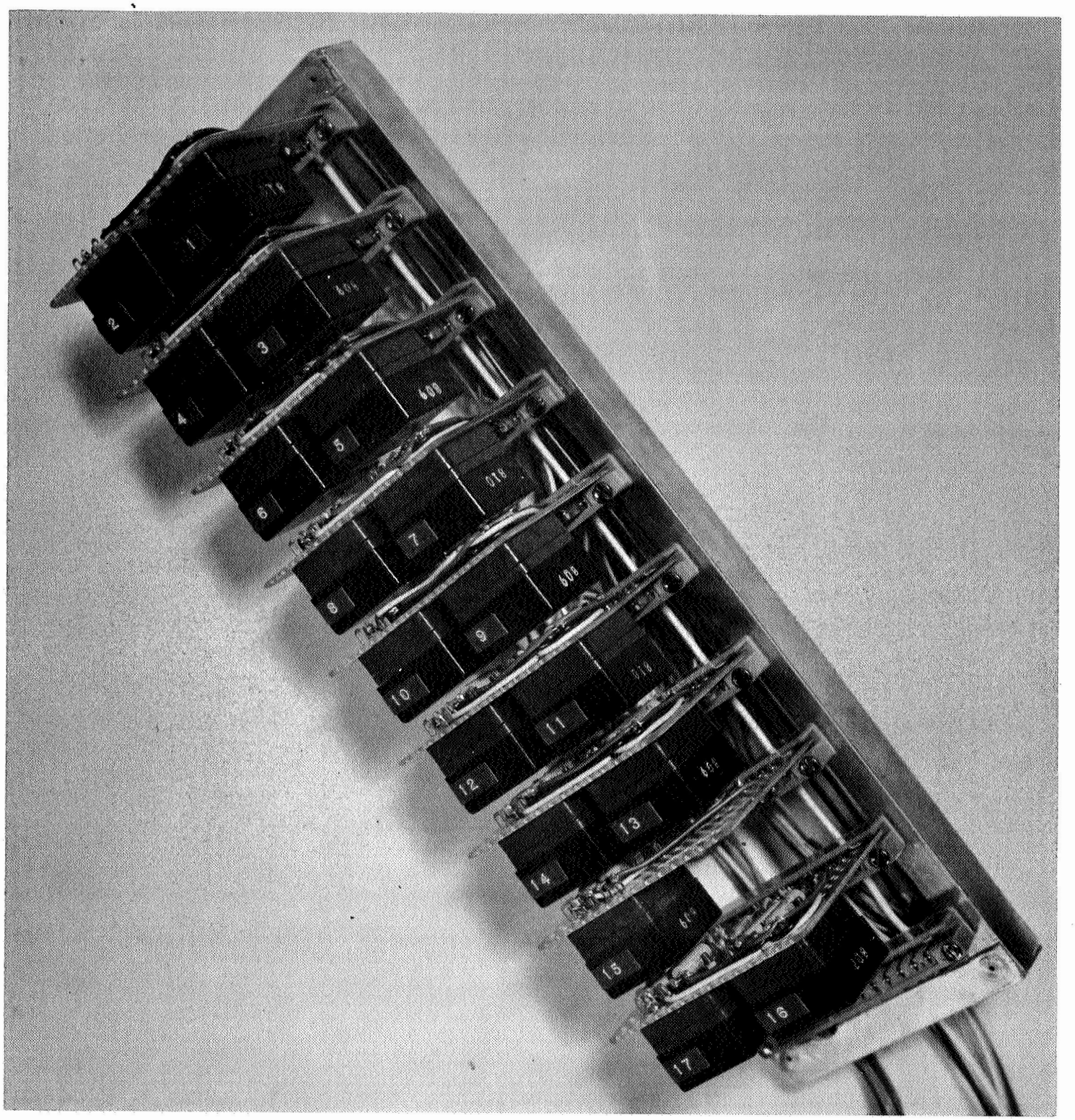
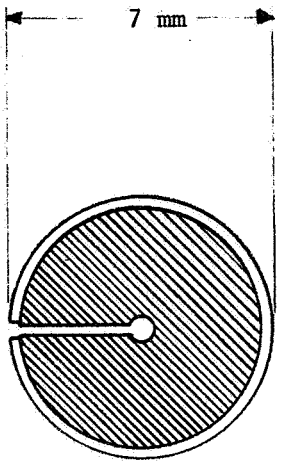
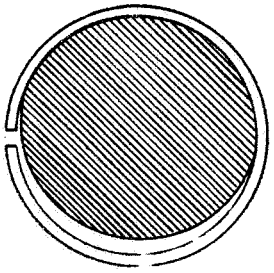


Fig. 4. Multi-channel EKG signal conditioning system.



(a) Original Design



(b) Improved Design

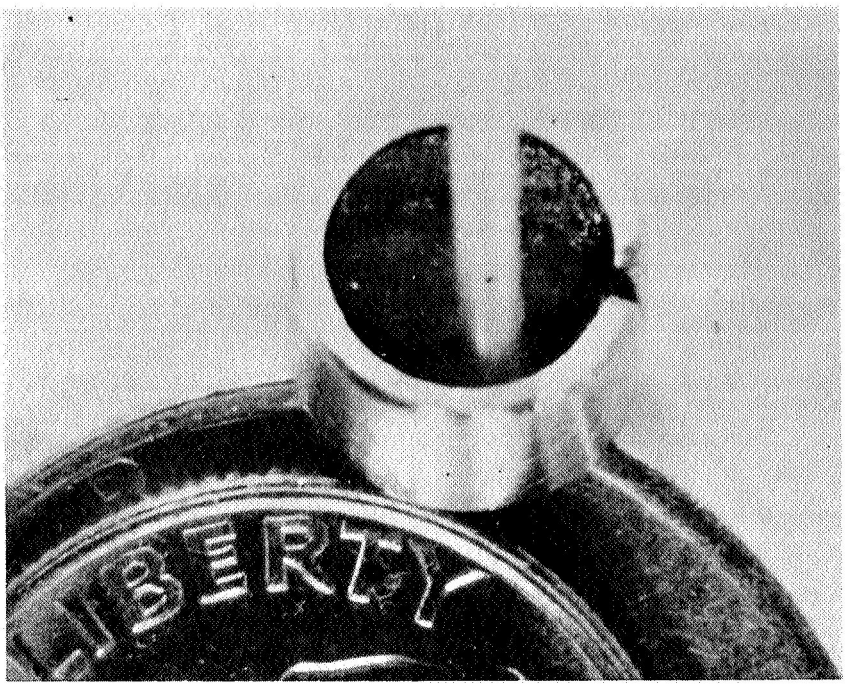
Fig. 5. Artery constrictor design.

of a stainless steel ring with a small opening as shown in the figure. The center shaded portion of the constrictor is an ameroid plastic which swells considerably when immersed in a saline solution. When this device is placed around an artery, it absorbs fluid from the body and swells to close the artery within two to three days. The major problem with this device is that its operation is not predictable. The primary reason is that, when the ameroid itself attempts to swell, the forces within the ameroid tend to make the hole larger. However, since the ameroid is constrained by a stainless steel ring, the hole actually gets smaller. However, because of these conflicting forces the swelling process is somewhat erratic and leads to unpredictable performance. The Biomedical Applications Team suggested an alternative geometry which would improve the performance of the device. The suggested geometry is illustrated in Figure 5-b. In this case, the artery is inserted into the slot between the stainless steel ring and the ameroid. When the ameroid swells, the opening is closed by a more "natural" expansion of the material than is the case with the previous design. This should result in more complete occlusion of the artery, and the time required for closure should be more accurately predictable. Experiments with occlusion of flexible plastic tubing indicates that a very positive closure of the tubing is obtained. Figure 6-a illustrates a segment of plastic tubing inserted in such a device before immersion in water. Figure 6-b illustrates the same device and tubing after immersion in water for 72 hours. These photographs indicate the complete occlusion which is obtained by this approach. At present a small number of experimental units are being fabricated, and physicians at Duke University plan to evalute their functioning during the next quarter.

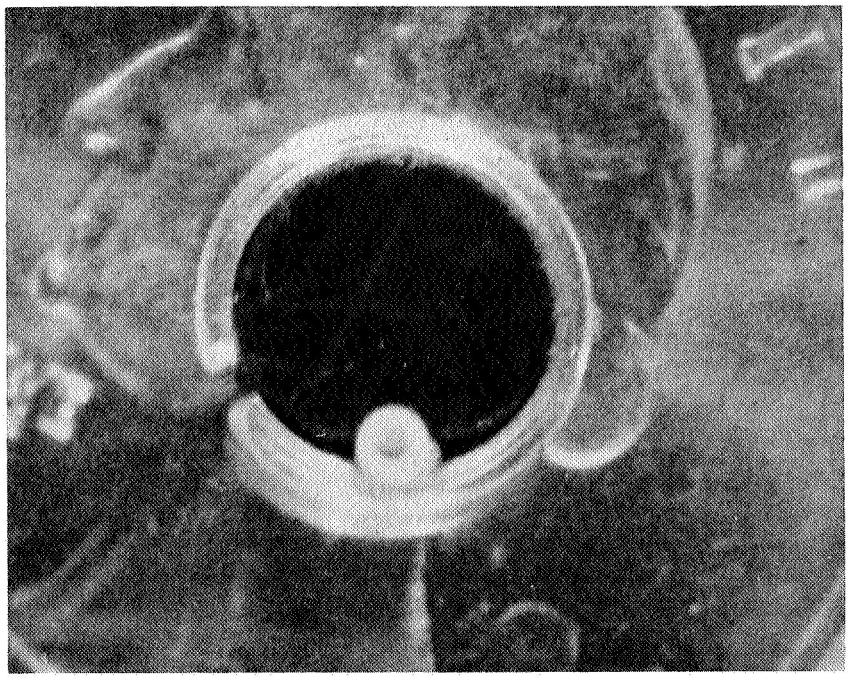
3.1.3 Hospital for Special Surgery

HSS-1 Method of Measuring and Telemetering Force Applied to Broken Bone Joints by Implanted Braces and HSS-2 A Method for Measuring and Telemetering Pressures on the Surface of Prosthetic Hip Joints

Information on the Ames pressure telemetry system has been forwarded to Dr. Amstutz at the Hospital for Special Surgery. The Ames unit represents a very reasonable approach to both problems HSS-1 and HSS-2. In the case of HSS-1, a force transducer must be substituted for the pressure transducer. Additionally, some re-engineering of the configuration of the pressure transducer will be involved in adapting the unit for implantation in a hip joint. In addition, Dr. Hartwig recently informed members of the Applications Team that a new plastic has been developed by TRW Systems under a NASA contract which may be applicable as a material for prosthetics



(a) Artery Constrictor Before Immersion



(b) After Immersion for 72 Hours

Fig. 6. Artery Constrictor.

such as the prosthetic hip joint. At present, the team is obtaining specifications on this new material to determine its applicability both as a prosthetic hip joint and as a material for prosthetics in general.

Efforts at the Hospital for Special Surgery are being directed toward both fabricating and purchasing experimental telemetry units.

3.1.4 North Carolina State University

NCSU-1 The Application of Mathematical Modeling Techniques to the Cardiovascular System

During this quarter, contact has been made with Dr. B. J. Ceremele of the Biostatistics Department at North Carolina State University. Initial discussions outlined the basic characteristics of the Biomedical Applications Team program. The research activities of Dr. Ceremele were discussed, as well as means whereby the Biomedical Applications Team might interact in this program. Dr. Ceremele is engaged in a research program to apply mathematical modeling techniques to the vascular system. He is particularly interested in work which may have been done by NASA in the application of mathematical models. A search strategy was formulated to obtain this information. The search yielded 238 total citations. The search bibliography has been given to Dr. Ceremele, and he is presently evaluating the search prior to ordering documents. A computer evaluation form for this search is contained in Appendix A.

3.1.5 University of North Carolina Dental Research Center

UNCD-1 A Method of Producing Silver-Copper and Silver-Tin Alloys in Powder Form with Spherical Shape and with Particle Sizes in the Range of 2 to 4 and 6 to 10 Microns

A problem abstract has been written on this particular problem for a number of months.* During this quarter, Mr. Jim Benson of the Rocketdyne Division of North American Aviation contacted us concerning a possible solution to this problem. It involved the application of a means of preparing spherical metal particles developed under a NASA-sponsored program. Full information on the process was requested and received from North American in January.

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*Biomedical Applications of NASA Science and Technology, Contract No. NSR-34-004-035, Final Report, 15 June 1966 to 14 June 1967

Dr. D. F. Taylor, the dental researcher who originated the problem, was contacted, and the information concerning the North American process was given to him. Analysis of the data showed that 50% of the mass of the particles produced by this process could be made to lie within a 2 to 1 size range. For example, 50% of the mass could be made to lie in the 2 to 4 micron range. However, the particle size distributions were such that the distribution curve always tailed off to zero. This means that there is a continuous distribution of particles from the selected particle size which is desired all the way down to zero. Unfortunately, the presence of the smaller particles cannot be tolerated, and a screening process would be necessary to separate the particles into the proper size fractions.

Further conversation with Dr. Taylor revealed that powders having size distributions very similar to those produced under the North American process can be obtained commercially from the Kerr Manufacturing Company of Detroit, Michigan, who is producing these powders under a Federal-Mongol patent. This particular process, while not identical to the process used by North American, has a marked similarity. In fact, the basic principles appear to be the same. After this analysis, Mr. Benson at North American was contacted to determine if particle size distributions could be obtained with their process which do not tail off to zero. No further information has been received from North American at this time. However, because of the shape of the particle size distribution curves produced by this process, it appears that the materials produced by such a process would not be significantly better for the purposes of the dental researcher than the commercially available powder.

UNCD-3 A Means to Obtain Rapidly a Pictorial Representation of the Temperature Distribution of the Interior of the Oral Cavity in Humans

This problem has been under discussion for some time in order to clearly define the requirements of the researcher. During this quarter a problem abstract has been prepared and submitted for distribution. A copy of the problem abstract is included in Appendix B.

UNCD-6 A Small Sensor to Measure Viability of Human Teeth

This problem also has been under consideration for several months. Researcher requirements have been finalized, and a problem abstract has been prepared and submitted during the quarter. A copy of the problem abstract is included in Appendix B.

UNCD-11 An Improved Bacteria Sampling Technique

A search was begun in this area during the last quarter, and a number of documents were considered to be of interest by the researcher. During this quarter the documents have been received and forwarded to the researcher. A number of documents were of direct interest. The search revealed that several areas of common interest exist between infectious oral disease research and NASA research. They are:

1. Asepsis and the technology for detecting and monitoring microbial cross contamination as applied to clinical dentistry.
2. Methodology of disinfection and sterilization and aseptic control of airborne microorganisms.
3. Sampling of oral and respiratory passages for detection of microorganisms.
4. Bacterial identifications related to occurrence and changes of pathogenic and indigenous species of the oral and respiratory passages.
5. Effects of changes in environment, developmental physiology, and stress on oral and upper respiratory flora.

Of particular interest and assistance to the researcher were several articles on sampling culture procedures and flora changes of personnel enclosed in controlled chamber environments for long periods of time. A computer evaluation report on the search conducted under this problem is contained in Appendix A.

A problem abstract has been submitted on this problem during the quarter, and a copy is included in Appendix B.

UNCD-12 A Method of Measuring Subglottal Pressure

This problem involves the measurement of air pressure in the subglottal region in children with varying degrees of cleft palate defects. The researcher is seeking to correlate the degree of speech intelligibility with the amount of palate damage in a clear manner. A significant parameter is the ability of a child to generate a pressure in the subglottal region. Measurement of this parameter, however, is difficult and extremely uncomfortable to the children. In addition, the currently available techniques are difficult to calibrate so as to obtain meaningful air pressure measurements. A problem abstract has been prepared during the quarter and submitted. A copy of the problem abstract is contained in Appendix B.

Also, during the quarter an attempt has been made through selective literature searching and personal contact to locate a pressure transducer that is suitable for application to this particular problem. The result is that the optical pressure transducer developed by Dr. Max Anliker at the Ames Research Center appears to be the best available device to perform the measurements required in this application. Mr. George Edwards of the Technology Utilization Office at Ames Research Center has supplied the most important component of the pressure transducer to the RTI Biomedical Applications Team to use in evaluating the transducer as a device for direct measurement of pressure in heart chambers.* When fabrication of an experimental unit is completed, it will be demonstrated to the researcher and is expected to solve his problem. There may be other and better solutions to the problem, so the problem abstract has not been withdrawn. It is not unlikely that someone in the NASA system may have a better idea for instrumenting this type of pressure measurement. In any event, however, NASA technology has been identified which can be applied to solve this problem.

UNCD-13 An Economical Dry Heat Sterilization Apparatus

Dr. J. J. Crawford of the Dental Research Center needed to know the available commercial sources of dry heat sterilization equipment. The particular need is for dry heat sterilization units of reasonably small size to be incorporated into laboratories in the dental school. Using the facilities of STRC and the vendor files of the Research Triangle Institute, a number of sources for dry heat sterilization equipment was identified, and a list of manufacturers was furnished to the researcher. The information furnished was adequate to permit the researcher to procure additional information on the various types of sterilization units available so that the unit most suitable for their purpose can be chosen. During this quarter, complete manufacturers's information has been received by the researcher, thus, resulting in a satisfactory solution to the problem.

UNCD-14 Design of Clean Rooms, Especially Laminar Flow Clean Rooms

The Dental School of the University of North Carolina is now in a building and expansion program to increase their facilities. Information is needed on the design of clean rooms. In particular, laminar flow clean rooms were considered to be most appropriate. To aid in initial planning and to provide an information background upon which to base clean room design decisions, information on advanced

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* Biomedical Applications Team, Contract No. NSR-34-004-045, Quarterly Progress Report 2, 15 September 1967 to 14 December 1967

clean room design was needed. A selective search of the NASA literature revealed a number of documents on clean room design. Several were extremely pertinent and very complete in their specification of design criteria. These documents were furnished to the researcher and will provide the basis for the evolution of the design of the clean room facilities in the new Dental School building.

3.1.6 University of North Carolina Medical School

UNC-38 Electromyograph as an Aid to Hand Rehabilitation

In recent discussions with a number of individuals at the Hand Rehabilitation Center at the University of North Carolina, a number of technology-related problems and requirements were considered. One area which is of particular interest at present is the use of electromyographic signals in hand rehabilitation Miss Irene Hollis and associates at HRC have used EMG monitors which produce an audio tone proportional to electrical activity in hand muscles as an aid to retraining muscles in damaged hands as described in the following. Consider a case in which a particular muscle in one hand of a patient is capable of proper functioning but, due to a long absence of use because of an injury, the patient can no longer exercise voluntary control over the muscle. The retraining technique involves attaching electrodes to the same muscle on the undamaged hand so that the patient can hear a signal proportional to the muscle activity in this muscle. The patient is made aware that he can detect muscle activity that is so slight that visible movement does not result. After a period of time, he relates this very weak muscle activity with the presence of muscle stimulation by his voluntary nervous system. The EMG electrodes are then transferred to the damaged muscle which is to be retrained, and the patient is encouraged to concentrate on duplicating the same sense of awareness of stimulation and weak muscle activity in the damaged area. In many cases, the paralyzed or damaged muscle has sufficient innervation remaining to allow its detection by the monitoring system. When this is the case, a gradual improvement in voluntary muscle control can be achieved. The major problem with presently available equipment is

that the monitor is too sensitive to noise, not sufficiently stable to give reliable operation, and so bulky that it interferes significantly with the re-training process. The Applications Team at present is making a survey of presently available EMG equipment to determine if a better instrument is available. Information on an improved EMG audio monitor developed at Walter Reed Army Medical Center has been supplied to the investigators, and we are advising them on the approximate cost of their reproducing a similar unit. The investigators are also evaluating Search No. 680, Electromyography, and a number of selected documents from that search to determine if improvements in equipment or better alternate approaches exist.

UNC-39 Recording and Quantification of Electromyographic Signals

Miss Charlene Nelson and Mr. George Hamilton of the Division of Physical Therapy of the North Carolina Memorial Hospital are interested in an improved method for recording and quantifying electromyographic (EMG) signals obtained with existing diagnostic EMG equipment. This equipment now produces oscillographic records with up to 5-channels of EMG activity. Problems associated with the present operation include considerable overlapping of signals from adjacent channels due to the narrow paper width and also difficulty in obtaining quantitative measures of muscular activity from the present records. At present, the Applications Team is investigating the feasibility of directly recording these data in a form readible by a digital computer. The investigators at UNC are examining Search No. 680, Electromyography, for references relative to their research program.

3.1.7 Wake Forest University, Bowman Gray School of Medicine

WF-3 Prosthetic Valve for Urinary Tract

Consultations have again been held with the researcher on this problem during the preceding quarter. The researchers are actually working on this problem but have been unable to produce a device that is satisfactory from all standpoints. The problem is complex in that it involves a number of different aspects which are reviewed below. First, regardless of how one might go about designing a valve and a remote actuating device, there is a material problem in fabricating such a device. The specific material problem is that incrustation occurs on most materials which can be used for valve construction. This is, of course, undesirable since the incrustation build-up will lead to failure of the device. If the valve were to be constructed of a material on which incrustation occurred, then some means of cleaning the valve in situ would be required. Silastic has proved to be the best material available, from an incrustation standpoint. The operating life of the valve must be at least four years, since the operation required to implant the valve is a major one and cannot be performed frequently.

Aside from the incrustation problem, there is also the problem of remote actuation of such a valve. The valve must be constructed in such a fashion that it can be actuated from outside the body without invasive techniques, such as wires, etc. Finally, many of the patients requiring these valves also have damage which prevents normal operation of the bladder. As a result, these patients require, in addition to a valve that can be opened, a means of stimulating the bladder to cause contraction and emptying. Two NASA publications have been furnished to the researchers during this period: SP-5019 Advanced Valve Technology and SP-5905 Seals and Sealing Techniques. These particular publications were welcomed by the researchers and considered to be of relevance to their problem.

In addition, during this period extensive discussions were held with STRC to determine a search strategy which would yield specific, useful information, which may reside in the NASA information system, on the subject of prosthetic urethral valves. After rather extensive discussions which were required because of the difficulty of searching this particular area in the NASA information system, a search strategy was formulated, and a search was run. The result of the search was a yield of zero hits. We have not been able to modify the search strategy so as to obtain a useful search output.

It is difficult to overestimate the importance of this particular problem, since the most common cause of death in paraplegics is urinary infections. Because of the active interest of the researchers and their willingness to evaluate all suggestions, it appears advisable to rewrite the original problem abstract and to

expand it into a thorough discussion of all aspects of this particular problem. This analysis is currently under way, and it is expected that a new problem abstract will be generated during the next quarter.

WF-6 Seven-Channel, Portable, Battery-Operated Tape Recorder

Original efforts to solve this problem have been completely unsuccessful; although a NASA tape recorder has been identified as being capable of solving the problem. The particular unit is the biomedical tape recorder developed at the NASA Flight Research Center, Edwards, California. Mr. Clint Johnson, TUO at the Flight Research Center, has been contacted to determine if any of the biomedical recorders were available on a loan basis so that the researcher could evaluate its performance. Unfortunately, we have not been successful in obtaining any of these units because all units are in full-time use. Having obtained the manufacturer's name from the Flight Research Center, we contacted representatives of the Garrett AirResearch Corporation to determine the possibility of a redesign of the original equipment, eliminating many of the environmental requirements which should have added greatly to the cost of the NASA units. Talks with the manufacturer's representative have been singularly unsuccessful because of the cost quoted for development of such a device. Quoted prices were in the neighborhood of $50,000 for a four-channel unit. This is much too expensive for the particular use that the researcher requires.

Next, we initiated a thorough search of the commercial literature to locate any commercial magnetic tape recording devices which might fit this particular application. After considerable searching, we have located a portable, battery-operated tape recorder manufactured by Lockheed Electronics Company which appears to be capable of solving the researcher's problem. Information and prices on the recorder have been obtained and forwarded to the researcher who is presently in the process of evaluating this particular recorder for his use. The weight penalty of this unit is considerably more severe than that of the NASA-developed biomedical recorder in that it weighs four times as much; however, in this application it appears that the weight penalty can be tolerated, particular since the cost of the unit is less than $12,000. This is clearly a case of trading off weight advantage for a reduction in price. This can be regarded as a potential transfer, subject to final evaluation by the researcher as to the full applicability of the Lockheed unit.

WF-12 Variable Diameter Probe for Electromagnetic Blood Flow Meter

This problem is one posed by the Biomedical Application Team's consultant at Wake Forest University, Dr. George L. Malindzak, Jr. The Department of Physiology at the Bowman Gray School of Medicine is heavily committed to cardiovascular research.

One of the recurring problems is in the measurement of blood flow characteristics. Specifically, blood flow rate and volume measurements are needed with a higher accuracy than those which are presently obtainable. In addition, currently available equipment is rather cumbersome to use, and a simpler more accurate system is highly desirable. A search was made on blood flow meters, Bibliography No. 1128, in January. The search strategy was designed to be very specific, and an evaluation by Dr. Malindzak indicated that, while all of the documents were pertinent and contained very good information, most of the documents were already known to him and indeed were in his files. As a consequence, the decision was made to run the search again. This time the search strategy was broadened to include liquid flow measurement so that any novel techniques or developments outside the field of blood flow measurement which might be applicable would come to light in the search. This search was significantly larger with a total of 550 citations. Dr. Malindzak commented that this search is much better than the previous search, with much of the information in it being new to him. The results are currently being evaluated, and selected documents have already been ordered. A more comprehensive evaluation of the search and its application to the specific problem of blood flow measurement is continuing. Computer evaluation forms on both these searches are included in Appendix A.

WF-13 Radiation Detector for in vivo Measurement of Absorbed Dose

This particular problem has languished badly because of a misunderstanding concerning the way in which the Biomedical Applications Team should proceed in trying to obtain radiation detectors from Solid State Radiation, Incorporated. However, the researchers are still actively interested in pursuing the matter further and would apply radiation detectors in their research program if such detectors could be made available. When the requirement for an in vivo radiation detector was originally identified, a selective search of NASA publications was begun, and a Tech Brief describing just such a device was located. Since the device was developed at Manned Spacecraft Center, Mr. John Wheeler, TUO, at the Manned Spacecraft Center was contacted. It was discovered that the probes were originally developed under NASA contract for the Manned Spacecraft Center. Unfortunately, the contract was inactive, and no radiation probes were available from Manned Spacecraft Center for evaluation. Mr. Wheeler informed us, however, that the company which manufactured the units was Solid State Radiation, Inc., in Los Angeles, California.

The problem was discussed with Dr. H. S. Katzenstein, president of Solid State Radiation, Inc. He agreed that his probes would be useful in the proposed research program and, indeed, may be the only devices available which could perform the desired function. Because of his personal interest in the use of radiation detectors in such

a program, Dr. Katzenstein volunteered to come to the Research Triangle Institute and meet with the biomedical investigators from Bowman Gray School of Medicine to discuss the problem. At this meeting, the general feeling was that the best way to proceed in obtaining radiation detectors from Solid State Radiation, Inc., was for the biomedical researchers at Bowman Gray School of Medicine to negotiate directly with Dr. Katzenstein to obtain sample units which could be used to implement their research program. Later, Dr. Katzenstein suggested that the researchers contact Dr. Hodge Wasson of the Atomic Energy Commission because Solid State Radiation is building a number of probes under AEC contract for use by medical researchers.

In the meantime the researchers at Bowman Gray had submitted a proposal to the Forsyth County Chapter of the American Cancer Society to obtain funding that would cover the cost of patient processing required to implement this program. The proposal was favorably reviewed, and a grant was given to the researchers for this purpose. This grant application and a request for information as to how Bowman Gray could participate in the AEC program in such a fashion as to obtain the radiation detectors manufactured by Solid State Radiation, Inc., was sent to Dr. Wasson by Dr. Damon Blake, Director of Radiation Therapy at Bowman Gray School of Medicine. At this point, it appears that a breakdown in communications occurred, so that the situation essentially became dormant.

Up to this time the Biomedical Applications Team had not been actively involved. However, in January it seemed that some action needed to be taken to clarify the overall situation. Thus, we felt that it was perhaps time that the Biomedical Applications Team began to participate more actively in this problem area. To this end, Dr. Q. L. Hartwig was contacted for advice on the exact procedure for getting the situation off dead-center. He volunteered to call Dr. Wasson and to determine: (1) whether or not radiation probes could be made available to implement the research program at the Bowman Gray School of Medicine, and (2) if such was possible, what steps might be necessary to obtain the radiation probes. It was suggested that the Biomedical Applications Team call Dr. Wasson and discuss the problem. Dr. Wasson was contacted, and the overall history of this particular problem was outlined to him. After discussion, Dr. Wasson advanced the belief that it was distinctly possible that conditions might be found under which the radiation probes could be supplied to the Bowman Gray School of Medicine. To further clarify the necessary arrangements which must be made, Dr. Wasson felt that direct contact with Dr. Katzenstein and Dr. Blake were the next order of business. These steps are being taken immediately.

WF-22 Improved Methods for Presenting and Enhancing Autoradiographic Scan Data

This problem is one of those for which a technology has been identified within NASA, but the technology is not available for use by the researcher. Specifically, the computerized image processing system at JPL which was used to enhance the Ranger photographs and others could be employed to provide the enhancement required in this particular area of study. Direct solution of this problem using digital image processing techniques must await the availability of an image processing system.

The Research Triangle Institute is currently seeking to establish an image processing center; however, the physical existence of such a center must, of necessity, lie somewhere in the future. We have discussed the overall problem of utilizing autoradiographic scan data with Dr. Meschan of the Radiology Department at Bowman Gray School of Medicine who originated the problem. These discussions led to the conclusion that since an image processing facility was not going to be available in the immediate future, perhaps it would be advantageous to obtain further information on NASA developments in the overall field of autoradiography. To this end, a retrospective search was made of the NASA information system on the subject of autoradiography. This search, No. 1130, has been given to Dr. Meschan and other members of the Department of Radiology for their information and review. A computer evaluation form for this search is included in Appendix A.

WF-24 A Respirator Control System That Adjusts Both Volume and Rate According to Body Needs Determined by Continuously Monitoring the Partial Pressures of Oxygen and Carbon Dioxide in the Blood Stream

This problem is basically the same as WF-31 in intent; however, it represents a departure in method of implementation. It requires monitoring of the partial pressures of gases in the blood stream by a non-invasive technique so as to control the respirator volume and rate to maintain the proper concentration of oxygen in the blood. Measurement of oxygen and carbon dioxide in the blood is considered to be a more fundamental measurement than measurement of oxygen and carbon dioxide in the expired air; however, accurate measurement of oxygen and carbon dioxide in the blood by non-invasive techniques represents a more difficult problem. As a result, the matter of providing a controlled respirator system was broken into two problems.

A respirator control system based on monitoring expired gases is no doubt feasible within the current technology (size and costs restraints appear to be the major factors barring wide-spread application of such a system). A respirator control system based on non-invasive measurement of 0_2 and $C0_2$ partial pressure in the

blood may require the development of new technology to provide the sensors which are necessary to implementation. Search No. 1094, "Measurement of Oxygen and Carbon Dioxide in Blood and in Expired Air" was prepared in response to WF-24 and WF-31 since they both relate to measurement of oxygen and carbon dioxide and since the problems are intimately related and pursued by the same investigators. This search yielded 262 citations and is being evaluated by the researchers at the present time. A computer evaluation report on this search is presented in Appendix A.

WF-28 Blood Flow Volume and Blood Flow Rate in Vascular Systems using Indicator Concentration Methods

A problem abstract was prepared during the previous quarter. During this quarter, a search was made on the subject of Liquid Flow Measurement. This Search, No. 1162, was run for Dr. Malindzak and is related to problem WF-12. Since the scope of this search includes all methods and techniques of liquid flow measurement, including blood, it has sufficient utility so that it has been possible to use it in application to other related problems. Specifically, Search No. 1162 has been made available to Dr. Rapela, the originator of this problem, for his review and analysis.

WF-29 An Electrode for Measuring Hydrogen Ion Concentration and Carbon Dioxide Partial Pressure in the Blood

A problem abstract was prepared during the previous quarter. During this quarter, further activities have been devoted to the procurement of a number of documents directly applicable to this problem. A publication was obtained through STRC from the U. S. Air Force School of Aerospace Medicine, Brooks Air Force Base, Texas, on an electrochemical technique for measuring carbon dioxide content of blood. This report N 67-30226 describes a technique which appears to fully overcome the difficulties associated with this problem as described by Dr. Rapela. The technique employs a tris(hydroxymethyl)aminomethane in the isolated electrolyte, rather than the bicarbonate-potassium chloride electrolyte conventionally used. Two-thirds of the full electrode response can be reached in 30 seconds, compared to 90-120 seconds for the conventional electrode technique. The improved electrode also has better stability characteristics. The document has been under evaluation for some period of time. Because of circumstances associated with his research and teaching program, Dr. Rapela has not been able to provide further feedback. This seems a clear case in which technology has been identified that will solve the problem. Further discussions are necessary to explore means by which the solution can be implemented in Dr. Rapela's research program.

WF-30 An Improved Blood Vessel Constrictor

Additional discussions have been held with Dr. Malindzak to clearly define the requirements for the improved blood vessel constrictor. This information has been obtained, and a problem abstract has been submitted. A copy is included in Appendix B.

WF-31 A Servo-Controlled System to Measure pO_2 and pCO_2 in Expired Gases and to Control the Operation of Respirators

This problem is the subject of great interest in the department of surgery. A number of investigators are interested in the problem from several aspects. One aspect involves the treatment of patients who have normal lungs but who through some circumstance, for example, use of drugs, have temporarily lost the ability to breathe. It is generally felt that the treatment of such people could be done more efficiently and without the danger of over-ventilation if a means of sensing the components of the expired gases could be implemented to control the operation of the respirator so as to achieve proper respiration in the individual. Another aspect involves the use of respirators on patients following extensive surgery and patients in the intensive care units. Further discussion on this problem is continuing.

A selective, manual search of the NASA literature has been conducted by STRC, and several publications have been forwarded to the researchers for their evaluation. They are: Contract Report No. 619, "Instantaneous Monitoring of Multi-component Expired Gases," and CR-741, "The Design, Fabrication and Feasibility Testing of a Prototype Airborne Respiration Analyzer." These basically deal with the application of mass spectrometer techniques to the monitoring of expired gases. We have attempted to obtain demonstration units from Langley Research Center, but they are not available. Supplementary to this effort, a careful perusal of the commercial literature has led to the identification of a small, self-contained mass spectrometer unit which may be suitable for respiration analysis on a breath-by-breath basis. The unit is a Quad Model 160 Laboratory Mass Spectrometer. It has a self-contained vacuum system and is small enough to be usable under the conditions extant in intensive care units and operating rooms. In addition, its cost are relatively reasonable when compared to other units presently available. Full information, including prices, have been given to the researchers at Bowman Gray for their evaluation and analysis. Replies are expected in the near future. In the meantime, further information is being gathered on the problem, and a problem abstract is being prepared. In addition, a full retrospective search of the NASA information system has been conducted so as to provide

information on two problems, specifically WF-31 which involves the measurement of oxygen and carbon dioxide in expired gases and WF-24 which involves the measurement of oxygen and carbon dioxide in the blood. A single search was prepared for these two problems because of their close relationship to each other and because the investigators for both problems are the same people. This search, No. 1094,"Measurement of Oxygen and Carbon Dioxide in Blood and in Expired Air," resulted in 262 citations. A computer evaluation form on this search is included in Appendix A. The search is in the hands of the researchers for evaluation and analysis.

WF-32 Oxygen Toxicity Effects

In discussions with Dr. R. A. Kemp, an area of clinical practice which is becoming of increasing concern to people in patient care was raised, i.e., the matter of oxygen toxicity. It is necessary that a certain amount of oxygen be present in the blood in order to sustain life. It is not infrequent for patients with damaged lungs to exhibit an inability, using normal atmospheric air, to maintain the proper oxygen level. It then becomes necessary to provide a higher concentration of oxygen in the inspired gases that the patient breathes, whether the patient is on a respirator or is able to breathe himself. The problem occurs most frequently, however, with people who have sufficient disability such that use of a respirator is required.

When it is not possible to maintain oxygen in the blood at the proper level using atmospheric air mixtures, it then becomes necessary to switch to a higher concentration of oxygen. Conventional respirators do not include a provision for a continuous or even a number of step-wise increases in the amount of oxygen. The alternative to using atmospheric composition gases is to use 100% oxygen. Increasing evidence has been accumulated in recent years to indicate that serious effects can occur as a result of the use of 100% oxygen for prolonged periods of time.

The researchers at Bowman Gray are interested in: (1) how damaging is the inspiration of 100% oxygen on human beings; i.e., how severe are oxygen toxicity effects, and (2) how does the damage resulting from oxygen toxicity effects correlate with increasing or decreasing partial pressure of oxygen present in the inspired gases. Specifically, does the damage to tissue from high concentration of oxygen vary linearly with the partial pressure of oxygen, or is there a threshold value of oxygen partial pressure at which the damage exhibits a large step-wise increase? If the relationship between the partial pressure of oxygen present in inspired gas and the amount of damage caused by the oxygen toxicity effect was known, then the desirability of switching from inspired gases with an oxygen content

equal to atmospheric composition to one of 100% oxygen could be evaluated. One could then determine whether this is a reasonable procedure or whether physiological damage could be reduced by providing some means of varying the partial pressure of oxygen in the inspired gas so as to provide just enough oxygen to bring the blood oxygen to the proper level. This does not represent a research project of the investigator, but it is a definite matter of clinical concern. Since his schedule is such that he cannot devote a major portion of his time to this problem, he requested selected information rather than a full retrospective search of the NASA literature. Consequently, a manual search was performed at STRC, and twenty-three abstracts which appeared to be most pertinent were furnished to the investigator. Selected documents are currently being reviewed by the researcher.

WF-33 Biotelemetry

Members of the Department of Surgery of the Bowman Gray School of Medicine are interested in improving the quality of their patient monitoring in the intensive care unit. The present intensive care unit has approximately 15 beds located peripherally around a central nurse station. They have two hard-wire systems for monitoring EKG from two of the beds at the central nurse station. Present equipment is extremely bulky, both in the patient's room and at the nursing station, and requires physical attachments of wires to the patient. This clutter of equipment around the bed is extremely inconvenient, and they are very interested in some means of reducing equipment size and complexity while, at the same time, improving their monitoring facilities. Specifically, they would like to monitor one-lead EKG and respiration rate from each bed at the central nursing station. It is very desirable that wires not be attached to the patient; therefore, a telemetry unit is necessary. A conventional electrode system can be used for the EKG; however, an investigation of the different approaches to monitoring respiration will be necessary to determine the optimum technique.

Search No. 697 on Biotelemetry which has been updated through December 1967 was presented to Drs. R. A. Kemp and T. H. Irving of the Department of Surgery for their evaluation. In addition, information on the Ames miniature biopotential telemetry system was furnished in the form of the supplemental information brochure compiled by Ames. Evaluation of the Ames telemetry unit was very favorable, and it appears that the basic design would perform the telemetry function required. It is realized that there are a number of commercial monitoring systems which are presently available on the market. In this case less complex monitoring (and, consequently, less complex equipment) is required than that provided by currently available commercial monitoring systems. Indeed, the basic reason for promulgation

of this problem is the emphasis on providing a simple system for basic monitoring that does not involve bulky equipment or instrumentation on the individual or in the room.

WF-34 Fractionation of Gamma Globulin G

Dr. J. H. Meredith, Bowman Gray School of Medicine, Department of Surgery, has an interest in a program for evaluating certain specific effects of gamma globulin G. He expressed an interest in finding out whether anything exists in the NASA literature on fractionation of gamma globulin G. The problem was discussed with the applications engineer at STRC, and perusal of the indexed terms revealed that there are only three articles indexed under gamma globulin in the system. These three articles were pulled and examined; however, none of them related to gamma globulin G. The problem was again discussed with Dr. Meredith, and the possibility of writing a problem abstract was considered. Dr. Meredith felt that a problem abstract should not be written at this time. Consequently, this problem has been closed.

WF-35 Oxygen Tension in Tissue

A request was received from one of the medical researchers at Bowman Gray for information which may be present in the NASA information system concerning measurement of oxygen tension in tissue. He is conducting experiments on nerve damage in tissue and has noticed some evidence that certain nerve disabilities may be related in some fashion to oxygen deprivation in the nerve tissue. He is interested in other work which may have been done under NASA sponsorship in this particular area, as well as in methods and techniques for measuring oxygen tension in nerve tissue. A retrospective search of the subject yielded 273 total citations. The researcher is currently reviewing the search bibliography to select those documents which are relevant to his requirements. A computer evaluation form for this search, "Oxygen Tension in Tissue", is contained in Appendix A.

WF-36 Implantable Pressure Sensor and Telemetry Unit for Measurement of Fluid Pressure in the Cranial Cavity and WF-37 An Implantable Valve which Can Be Remotely Opened and Closed from Outside the Body

These two problems actually represent two segments of the same problem and, therefore, will be discussed together. Dr. D. L. Kelly, Jr., of the Department of Neurosurgery is engaged in research activities associated with the build-up of fluid pressure in the cranial cavity. Many people have a fluid build-up that occurs in the cranial cavity, and this pressure must be relieved. This is usually accomplished by inserting a pickup tube inside the cranial cavity and running a piece of tubing down underneath the skin in the rear of the head, finally discharging

the fluid into one of the blood vessels where the fluid is dispersed. A special one-way valve known as a Holter valve is used to prevent passage of blood into the cranial cavity. Not infrequently, this valve will stick closed, and pressure will begin to build up in the cranial cavity of the individual. In addition to this particular difficulty, the present valve does not permit any control over flow, i.e., it is a one-way valve which is always open in the forward direction and always closed in the reverse direction. For example, it is desirable on certain occasions to be able to close off the valve and to observe the rate of pressure build-up. Then, at some selected pressure level, the valve would be opened permitting the fluid to drain out of the cranial cavity. Since the drain tube and valve are permanently implanted (unless it becomes necessary to remove the valve because it becomes clogged) operation of the valve must be accomplished from outside the body without external wires or connection. In addition, monitoring of the pressure in the cranial cavity must be accomplished by means of a small pressure transducer and then telemetered outside the body for pick up.

These two problems have been considered from a number of standpoints. Particularly in the matter of the pressure sensor and telemetry unit, the Ames implantable pressure biotelemetry system seems very feasible for this application. Indeed, we have encountered many applications where the Ames biotelemetry units appear to be a logical choice of technology to solve the problem. We have attempted to obtain sample units from Ames, but they are not available. To aid in the application of this aerospace technology the Research Triangle Institute, independently of the Biomedical Applications Team contract, has decided to fabricate a demonstration telemetry system based on the Ames unit which can then be used by the Biomedical Applications Team for demonstration purposes. Construction of such a unit will also permit the Biomedical Applications Team to provide definitive cost data to researchers interested in incorporating such biotelemetry systems into their research programs.

The problem of the implantable valve is intrinsically a more difficult problem. We have been seeking a prosthetic urethral valve for more than a year with absolutely no success. There is cause to hope, however, that a valve for this application can be discovered because: (1) the size restrictions are not as severe as in the case of the prosthetic urethral valve, (2) the problem of incrustation is not present, and (3) the surgical procedures required for installing the valve itself are not nearly so severe. Further information is being gathered on these two problems at the present time, and a problem abstract will be prepared in the near future.

WF-38 An Inexpensive Sterile Fabric for Sheets, Operating Room Gowns, Tissue Transfer, Etc.

In discussions with Dr. J. H. Meredith of Bowman Gray, he has mentioned the need for an inexpensive sterile fabric for use in the hospital. It would be most desirable if it could have some active ingredient which would act as a sterilizing agent whenever the surface of the fabric comes into contact with bacteria. This inquiry was prompted by the recent development of a hexachlorophene-impregnated plastic film which makes a step in this direction but does not have the degree of sterile action desired. Because of this commercial development, Dr. Meredith wondered if perhaps some such fabric might have been developed by NASA as a result of the extensive work on spacecraft sterilization which has been performed. A manual search has been performed at STRC to ascertain whether there is any reference to such a material in the NASA information system. The results of the manual search were completely negative; therefore, a study is being made to determine whether it would be fruitful to run a complete retrospective search on this problem.

WF-39 Information on The Physiological Effects Arising from The Use of Short-Lived Radioisotopes in Treatment and Autoradiography

This problem is the result of discussions with Dr. D. J. Pizzarella, Department of Radiology of the Bowman Gray School of Medicine. In recent years short-lived isotopes have been developed which have been used in treatment. Generally, these isotopes have been administered on the basis of not exceeding a specified total dose. However, because of their extremely short half-life, the dose rate is extremely high. It is well known that the response of living cells to radiation varies with the dose rate. The severity of tissue damage as a result of extremely high dose rate is attributed to the fact that radiation damage occurs repetitively before the cell can recuperate from a previous hit from ionizing radiation. There are felt to be other perhaps more subtle reasons for the differential response of living cells to varying dose rates. Dr. Pizzarella wishes to determine whether such information resides in the NASA system. This information would be valuable not only from a clinical standpoint, but for two other reasons. First, Dr. Pizzarella is engaged in the teaching program of the university and wishes to incorporate such information into a course on autoradiography being given to resident physicians. Second, because of a personal interest in this particular area of investigation and the desire to pursue research in this area, Dr. Pizzarella wishes to use information in the NASA system as the basis on which to generate a research grant application in this area.

Another related area in which Dr. Pizzarella requested information on NASA activities is discussed in problem WF-45, Sensitivity of Animal Cells to Radiation as a Function of Amount of Oxygen Present in Tissue and as a Function of Radiation Dose Rate. Because these two problems are closely allied, it was decided to combine them into a single problem for search purposes. As a result, a single retrospective search, ("Short Half Life Radiation Medicine," Search No. 1212) has been made. This search yielded 54 citations. A computer evaluation form describing this search is contained in Appendix A.

WF-40 Localization of Blood Pools and Location of Blood Leaks in Various Cavities of The Body

This problem was obtained from Dr. T. F. O'Brien, Jr. Several methods for accomplishing localization of blood pools were discussed. Dr. O'Brien is interested in techniques, which can be clinically applied, that provide accurate location of blood pools and blood leaks. Additional discussions will be necessary during the next quarter to further define this problem.

WF-41 A Low Cost, Swallowable, Temperature-Sensing Telemetry Capsule

This problem originated with Dr. R. M. Kerr who is interested in monitoring temperature in various portions of the gastrointestinal tract. A low-cost unit applicable to clinical medicine is desired. Only an abbreviated preliminary discussion has been held because of the fact that Dr. Kerr's schedule has not permitted a complete discussion. Further discussion will be held during the next quarter.

WF-43 Means of Defining Driver Tasks for Automobile Drivers

Dr. J. H. Meredith who is involved in the highway safety program in the state of North Carolina has a requirement to quantitatively define the driver task for automobile drivers; that is, to break down and classify the elements of task performance which are involved in driving an automobile. He is interested, as a first approximation, in generalized methods of task definition. It seemed logical that rather extensive study should have been made of the astronaut task and that a large amount of information should be available on the particular application of task definition techniques to the astronaut's job. Dr. Meredith wished to examine the techniques to see in what measure they can be abstracted for use in defining automobile driver tasks. As a result, a search on "Task Definition," Bibliography No. 1246, was made by STRC. This search yielded 48 citations. It is presently in the hands of the researcher who is evaluating the abstracts. A computer evaluation form on this search is contained in Appendix A.

WF-44 A Means of Reducing Dose Rate While Taking X-ray Cine Radiographs

In discussing operational procedures with Dr. I. Meschan, Chairman of the Department of Radiology, he pointed out that, whenever cineradiographs of a patient are taken, the X-ray dose rate must be increased by a factor of 5 to 10 over that required for still photographs in order to obtain adequate cineradiographs. Dr. Meschan is interested in a means of reducing the dose rate, while still obtaining the same information as they now obtain using X-ray cineradiographs. There are a number of approaches to this problem which vary from increasing the sensitivity of the phosphor used in the camera tubes and other equipment improvements to increasing the quantum efficiency of X-rays in producing visible photographable images on the camera tube. This type of improvement generally requires a time-consuming and very expensive developmental program unless a new and completely novel idea is obtained. Even in the event of a novel idea which could permit reduction of dose rate while obtaining the same amount of information presently available, a considerable amount of developmental time and funding would be involved before it could be reduced to clinical practice.

On the other hand, one can approach this particular problem from the standpoint of image processing. For example, it might be possible to reduce the dose rate and obtain very poor pictures which could then be enhanced by digital image processing techniques. No doubt the process of technology advancement will eventually utilize both paths to improvement in X-ray technology. The application of image processing techniques to this problem must await the establishment of an image processing facility in this area. The Research Triangle Institute is currently seeking funding for such a project; however, it has not proceeded at this time to the point where a definite time-table can be specified as to when the image processing facility may be available to medical researchers in the Research Triangle area. Further discussion of this basic problem will continue during the next quarter.

WF-45 Sensitivity of Animal Cells to Radiation as a Function of Amount of Oxygen Present in Tissue and as a Function of Radiation Dose Rate

This problem has already been mentioned in the discussion of WF-39 where it was pointed out that a joint search was undertaken to provide information on both of these problems. This problem centers about the fact that the presence of oxygen in tissue tends to worsen the effect of radiation on the tissue. In addition, the effect of oxygen depends on dose rate, that is, the effect of densely ionizing radiation on tissue is not affected by the presence of oxygen nearly as much as when sparsely ionizing radiation is used. These two effects and their interrelationships are considered to be important. Yet, the mechanisms involved in these effects

have not been clearly identified. Dr. Pizzarella is interested in any information residing in the NASA system which is the result of experimentation in this area and which affords an explanation of either of these two effects or their interrelationships. Further discussion of this problem will be continued during the next quarter.

WF-46 An Artificial Hand with Touch and Prehension Pressure Feedback to the Human Operator

Problems in prosthetics in the Department of Physical Medicine and Rehabilitation at Bowman Gray School of Medicine were discussed with Dr. E. H. Martinat. Dr. Martinat pointed out that there have been significant advances in recent years in the control of prosthetic hands. In fact, electromyographic (EMG) control is very good and has progressed to the point that control is essentially no problem whatsoever in prosthetic hands. The same, however, cannot be said about the terminal device, the prosthetic hand. It is still so crude that one must be almost totally paralyzed before one would even consider using it. The result is that, using EMG signals, a rather sophisticated control is available for a very crude device. There have been a number of attempts to improve the terminal device and increase its usefulness.

Generally speaking, the approach has been to provide advances in dexterity over the simple hook by using articulated fingers and a thumb to provide prehensile grasp and a preload or slip clutch type of feedback system for grasping objects with a definite pressure. Some of the more advanced units have used a feedback system which could detect objects that were slipping from the grasp of the artificial fingers and use this as a signal to increase the pressure until the objects ceases to slip in the grasp of the prosthetic hand.

This system, while a great improvement, still does not permit the type of information feedback which can fully utilize the capabilities of the EMG control. What would specifically be desirable is the restoration of a sense of touch that provides a feedback to the operator (i.e., the person wearing the device) rather than a feedback circuit which merely controls a motor. This lack of a sense of touch is considered to be the most fundamental failing of present-day prosthetic devices. Such an improvement needs to be made very badly; however, one must also keep in the mind the fact that prosthetic devices are extremely expensive. All efforts should be made to decrease the cost of these devices rather than to increase them.

Another factor of great pertinence is the matter of reliability and replacement of parts. For example, when a prosthetic device fails a trained specialist must be consulted to restore the prosthetic device to operating condition. A design

approach which would be advantageous is to design the prosthetic device so that all parts or at least those parts which are subject to mechanical breakage, are easily replaceable.

As can be seen, at this stage an overall problem in hand prosthesis has been raised which has a number of individual ramifications. Further discussions of these specific areas is expected to lead to more definite problems which can be reduced in scope to permit searching of the NASA information banks and also to permit problem definition so that problem abstracts can be written. This activity will continue during the next quarter. An old search in the general area of prosthetics was made for another researcher a number of months ago. This search has been updated periodically, and the original search plus updates through December 1967 have been furnished to Dr. Martinat to give him some idea of the scope of information residing in the NASA information system.

WF-47 Information on Techniques and Advances in Thermography

There are a number of researchers at the Bowman Gray School of Medicine who are interested in the application of thermographic techniques to their research area. Dr. H. D. Green, Chairman of the Department of Physiology, is involved in clinical temperature studies in peripheral vascular diseases and has been using thermographic measurements in his research areas. Dr. M. C. Conrad is also interested in these techniques. Because of this interest, a number of documents have been supplied on thermography to the Department of Physiology at Bowman Gray. A publication from the Brooks Air Force Base Aerospace School of Medicine on thermography of the human dentition has been extremely helpful. In addition, a number of summary articles on thermography and a number of specific articles on liquid crystals have also been furnished. Current expectation is that this information will be used to improve an already existing research program in the area of peripheral vascular diseases or to perhaps initiate a new program.

In this same general area, during this quarter Mr. Ernest Harrison, Jr., of the Research Triangle Institute's Biomedical Applications Team presented a Seminar on thermography to the Department of Physiology at Bowman Gray School of Medicine. Particular emphasis was on liquid crystals, and a demonstration was given using commercially available liquid crystal materials. The seminar was very effective; a number of researchers expressed interest in the application of liquid crystals to their areas of research. Discussions are continuing with these researchers to determine how liquid crystals or other thermographic techniques can be applied to their research areas. Complete information on currently available liquid crystal materials has been given to these researchers including ordering and pricing information.

WF-48 Information on Cardiovascular Systems

One of the major investigative areas being pursued in the Department of Physiology at the Bowman Gray School of Medicine involves the cardiovascular system. The Biomedical Applications Team has been asked to furnish information on NASA contributions in this particular area. As a result, a continuing program for furnishing selected pertinent documents has been undertaken as an information service to keep members of the department abreast of NASA contributions to understanding of the cardiovascular system.

WF-49 Information on Sensors, Transducers, and Electronic Circuitry Adaptable to Medical Applications

Dr. A. B. Denison of the Department of Physiology of the Bowman Gray School of Medicine has designed a number of sensors and associated electronic circuitry for use in medical instrumentation systems. He provides information and consultation to other members of the Bowman Gray School of Medicine on matters of instrumentation and circuitry. He has requested selected information on transducers, sensors, and electronic circuitry developed in NASA that are adaptable to medical applications. A number of specific documents in this area have been furnished to Dr. Denison.

WF-50 Application of Time-Series Analysis to Computer Processing of Biomedical Data

Another service furnished by the Biomedical Applications Team to the Bowman Gray School of Medicine during this quarter is in the area of consultation. Dr. G. L. Malindzak, Jr., of the Department of Physiology of the Bowman Gray School of Medicine is actively engaged in computer analysis of physiological data. During this quarter he has expressed an interest in the application of time-series analysis to some of the programs on which he is working. He requested basic information in this area from the Biomedical Applications Team. The Biomedical Applications Team contacted Dr. D. F. Palmer of RTI who is a specialist in signal analysis techniques. Dr. Palmer furnished information on basic reference texts which he considered useful to Dr. Malindzak. After Dr. Malindzak had reviewed these texts, a consultation between Dr. Malindzak and Dr. Palmer was arranged wherein they discussed Dr. Malindzak's problem. Dr. Malindzak was well pleased with the consultation, and a positive transfer of information has occurred.

3.2 Presentations and Demonstrations by Members of the Biomedical Applications Team

During the preceding quarter, Dr. Brown was invited to discuss digital image processing before a number of investigators of the Departments of Radiology and Pediatric Cardiology at the Duke University Medical Center. The presentation stressed techniques developed and used at the Jet Propulsion Laboratory and applications of these techniques in the medical field. The same subject was discussed briefly at a conference held in Houston at the Manned Spacecraft Center on February 12-13 which was sponsored by the National Institute for Child Health and Human Development and the Technology Utilization Division of NASA.

Also, Mr. Ernest Harrison, Jr., was invited to make a presentation to the Bowman Gray School of Medicine, Department of Physiology Seminar. The subject of the presentation was "Fundamentals of Thermographic Techniques, including Liquid Crystals, and Their Application to Medicine". A demonstration of the use of liquid crystals for surface temperature measurement on human beings was also given using commercially available liquid crystals. Approximately 30 professional and staff members attended, and great interest was shown in the application of liquid crystals to a number of specific problems facing individual researchers. Follow-up discussions have been held with a number of researchers as a direct result of this conference because of their interest in the application of liquid crystals to specific problems in their area of research. In addition, a large bibliography on liquid crystals obtained from Mr. James B. Beal, Marshall Spaceflight Center, Huntsville, a number of related papers obtained from a manual search of the NASA literature, and information on commercial sources of liquid crystals was distributed to researchers expressing interest. The information is currently being evaluated by a researcher who plans to incorporate thermographic techniques into a basic research program on which he is presently preparing a grant request. Further discussions with individual researchers on the use of thermographic techniques in their specialized area of research interest are scheduled.

A presentation was made to Dr. Grace Kirby of the Duke University Medical School on the application of liquid crystals to surface temperature measurements in human beings. Dr. Kirby is working with arthritic patients who have impaired circulation. It is desirable for her to be able to make quantitative determinations of surface temperature on the extremities of patients having circulatory difficulties. For example, it would be desirable to make measurements of the individual fingers of a given hand, as well as to determine the temperature of selected spots on the arms and other portions of the extremities. The use of liquid crystals to measure the

temperature of fingers of the human hand was demonstrated to Dr. Kirby. Then the relative applicability of this technique to her particular problems was discussed in detail. Dr. Kirby expressed great interest in the technique and wished to try it on a number of her patients. After further discussions, it was agreed that the Biomedical Applications Team would provide a number of liquid crystal samples over a selected range of temperatures near the temperature of normal human hands. With these samples, Dr. Kirby then proposes to test the technique in actual clinical application to patients. Should the technique prove feasible then it will be incorporated as a part of her routine clinical procedures. The liquid crystal samples required for this evaluation program will be compounded by the Biomedical Applications Team during the next quarter.

3.3 Quarterly Problem Review

The quarterly review of all problems which have been documented by the Biomedical Applications Team has been conducted, and those problems which are no longer considered active have been closed. There are various reasons for which problems are classified as inactive. As examples, a successful technology transfer has occurred, it has been determined that the researcher can not, for a number of reasons, apply the technology identified, or no useful technology could be identified. The problems which were closed without further activity during this quarter are listed below:

WF-4 Small Aperture Ultrasonic Transducers Having Large Capture Angle.

WF-7 Method of Correcting for Spherical Aberration in Ultrasonic Holograms.

WF-8 Techniques for Analyzing and Obtaining all Significant Information Contained in Ultrasonic Echo Pulses.

WF-10 Theoretical Treatments of Holography which Discuss Aberrations and Distortions.

WF-17 Helmet Containing Electroencephalograph Electrodes.

WF-18 Techniques for Averaging Evoked Nerve Responses that are Simpler and Less Expensive than Commercially Available Instruments.

DU-4 Measurement of Extremely Small Temperature Changes.

DU-12 Techniques for Enhancing Cineradiographs of Kidneys so that the Arterial Network within the Kidney can be Mapped.

UNC-6 Implantable Plastic Materials.

UNC-9 Analysis of Electrophoretic Scan Data.

UNC-13 Methods of Reinforcing Thermo-plastic Braces and Casts.

It should be noted that a number of Wake Forest problems in the field of ultrasonics and ultrasonic holography have been closed. This is a result of the fact

that Dr. F. L. Thurstone, who originated these problems at Wake Forest University, is no longer associated with the Wake Forest University. Dr. Thurstone is presently a member of the Duke University Medical School, and those problems of his which are still considered active are being given Duke problem numbers.

3.4 Related Activities

During the preceding quarter the Applications Team has directed a relatively small effort toward two problem areas outside the field of biomedical research. At the request of the Technology Utilization Divison of NASA, the team evaluated a number of reports on advanced communications systems for possible application in communications systems for law enforcement in cities. The documents were obtained as the result of a search performed by the Knowledge Availability Systems Center at the University of Pittsburg.

In discussions with individuals at the National Center for Air Polution Control, it was learned that there is a need for a temperature telemetry system which can telemeter air temperature data from zero elevation up to 1,000 feet. Information on the Ames temperature telemetry system has been supplied, and at present discussions concerning the most appropriate manner for implementing such a system are in progress.

In addition, the Biomedical Engineering Department of the Bowman Gray School of Medicine received a requirement from a researcher in the Medical School to fabricate a special-purpose, analog computer system to be used in a research program. The Biomedical Engineering Department at Bowman Gray presently has a shortage of trained personnel to perform this type of fabrication. As a result, they wished to examine the possibility of subcontracting fabrication of the computer to an outside source. The request was made through the Biomedical Applications Team that the Research Triangle Institute provide a quote on the design and fabrication on the computer. A quotation was worked up by RTI and delivered by the Biomedical Applications Team. The Biomedical Engineering Department at Bowman Gray School of Medicine has used this quote as a guideline and has expressed appreciation to the Biomedical Applications Team for its part in providing this type of service to them.

4.0 THE TECHNOLOGY TRANSFER PROCESS

As discussed in Section 2.0, one of the objectives of the Biomedical Applications Team program is to obtain a better understanding of the process by which transfers are accomplished and to use this information to improve the effectiveness of the Applications Team. Based upon the experience of the RTI Applications Team, we feel that an extremely important factor in technology transfer is simply exposing as many people as possible to the problems. This, in fact, is the principal reason for writing Biomedical Problem Abstracts and disseminating them to NASA centers. However, it is felt that communicating problems at a very early stage, possibly even before they are completely specified and in cases where problem abstracts are not appropriate, is also very important. Of course, one cannot communicate everything to everybody, so that compromises must be made in this area. It is strongly felt that dissemination of problems, even non-specific problem areas, among the three Applications Teams and consultants to these teams can be of great value. As one example, Mr. Lewis Berger of the Southwest Research Institute Biomedical Applications Team has been familiar for a number of months with the general problem areas involved in ultrasonic holography. Mr. Berger recently informed us of an article in the field of image processing which involves extending the frequency content of images recorded by a diffraction-limited system. This article has been of value to Dr. F. L. Thurstone who is investigating ultrasonic holography as a clinical diagnostic tool at Duke University. The information obtained, although not directly related to a problem which had been identified and specified, has aided Dr. Thurstone and the Applications Team in defining more clearly and precisely some of the problems involved in ultrasonic holography and, therefore, has aided the search for technology which can advance this particular research program. It is felt that this type of interaction between the three Applications Teams should be pursued actively and in a more formal manner.

One other factor which is related to the degree of effort that is applied to different problem areas on the part of the Applications Team is felt to be significant. It has been found that the most expensive part of the Applications Team process is that related to evaluating the results of information searches and, in fact, information obtained from any source. Thus, it is felt that when a specific technology, technique or concept is identified which appears to have somewhat general applicability in biological or medical research, a significant effort should be directed toward locating as many investigators as possible who can make use of the information. The types of information referred to here are those such as digital image processing, telemetry, thermography and specific transducers such as, for example, pressure sensors.

5.0 FINANCIAL SUMMARY

A summary of contract expenditures for the period 1 December 1967 through 1 March 1968 is presented in Table 1 below.

Table 1 - COST SUMMARY

Quarterly Costs:

Direct Labor	$10,048.00
Overhead	9,345.00
Direct Costs	2,388.00
Fee	1,305.00
Total Quarterly Costs	$23,086.00

6.0 PROJECTIONS FOR THE FOURTH QUARTER

The activities of the Biomedical Applications Team with the three major participating Medical Schools have emphasized different phases of the transfer process during this quarter. This is a result of response by the Biomedical Applications Team to the number and status of identified problems at each school, the changing status of specific programs at the medical schools, and the availability of consultants and researchers. For example, the activities at Duke University, where a backlog of problems had already been generated, have been directed primarily during this quarter to the location of solutions to these already-identified problems. On the other hand, there were very few active problems identified at Wake Forest University at the beginning of this quarter. As a result, the principal team activity at Wake Forest during this quarter has been centered on the identification of new problems.

During the fourth quarter, major emphasis at the Duke University Medical Center will be directed to the identification of new problems. This is a natural result of the fact that the primary activity at Duke University during the third quarter was directed to the solution of previously identified problems. Most of these existing problems are in the final stages of technology transfer. They will not require large expenditures of time during the fourth quarter so that time can effectively be allocated to the identification of new problems.

At the Bowman Gray School of Medicine, Wake Forest University, essentially the reverse situation exists. Team efforts during the third quarter have resulted in the identification of a large number of new problems. During the fourth quarter, the primary activity of the Applications Teams will be directed to the identification of aerospace technology which can provide solutions to these problems.

The Biomedical Applications Team has recently acquired a new member, Mr. R. L. Beadles, who is now responsible for team activities at the University of North Carolina Medical School. During the fourth quarter, attention will be given to expansion of the team activities at UNC.

Overall, the Research Triangle Institute's Biomedical Applications Team will continue assessment of the technology transfer process as it progresses at each individual medical school. In the light of the conditions existing at each medical school, careful evaluation will be made of each situation, and energies will be channeled into the specific activities at each medical school which will yield greatest benefit to the medical researchers at each school. It is felt that this approach will itself result in maximum utilization of personnel and time to achieve effective performance in the application of aerospace technology to problems originating from the medical schools served by the RTI Biomedical Applications Team.

APPENDIX A - Computer Evaluation Reports

COMPUTER EVALUATION REPORT

Biblio. # 679

Problem Name & Number: WF-33 - Biotelemetry units.

Title Search & RDC Number: Biotelemetry 0195

Date Search Initiated: July 15, 1966 updated through December 1967

Descriptors:

Biotelemetry
Physiological Telemetry
Telemetry
Medical Electronics
Medical Equipment
Biological
Life Science

Date Search Received: August 2, 1966 --updated December 1967

Number of Hits: 217

Date Documents Requested by Researcher: January 4, 1968

Number of Documents Requested & List of STAR Numbers:

SP-5023
Tech Brief 64-10171
Tech Brief 64-10624
Eight supplemental information documents on Ames biotelemetry units.

Degree of Relevance to Problem: extremely relevant; potential transfer

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1094

Problem Name & Number: WF-24, WF-29, and WF-31*

Title Search & RDC Number: Measurement of Oxygen and Carbon Dioxide in Blood and in Expired Air 0395

Date Search Initiated: December 11, 1967

Descriptors:

Measurement	Carbon Dioxide Concentration	Measuring Apparatus	
Partial Pressure		Blood	
Respiration	Analytical Chemistry	Blood Circulation	
Expired Air	Qualitative Analysis	Circulatory System	
Alveolar Air	Quantitative Analysis	Hypercapnia	
Exhalation	Volumetric	Hypocapnia	
Respiratory System	Analyzer	Hypoxia	
Oxygen Sensor	Gas Analyzer	Hypoxemia	Hyperoxia
Oximeter	Gas Composition	Oxygen	Carbon Dioxide

Date Search Received: December 15, 1967

Number of Hits: 262

Date Documents Requested by Researcher: 1-4-68

Number of Documents Requested & List of STAR Numbers:

N67-30226
A67-81971
CR-741
CR-619

Degree of Relevance to Problem: extremely relevant, potential transfer

Plans for Use of Information: Undetermined

* WF-24 - Respirator control system that adjusts both volume and rate as well as other parameters according to body needs determined by monitoring continuously the partial pressures of gasses in the blood stream.

WF-29 An electrode for measuring hydrogen ion concentration and CO_2 partial pressure in the blood is needed. Response should be 30 seconds or less. Currently available devices have a response time of 90 - 120 sec.

WF-31 A servo-controlled system to measure pO_2 and pCO_2 in expired gases and to control the operation of respirators.

COMPUTER EVALUATION REPORT

Biblio. # 1128

Problem Name & Number: WF-12 - Variable diameter probe for electromagnetic blood flow meter.

Title Search & RDC Number: Blood Flow Meters 0395

Date Search Initiated: January 22, 1968

Descriptors:

Flow Meter
Flow Measurement
Blood
Blood Flow
Indicator
Dilution

Date Search Received: January 24, 1968

Number of Hits: 15

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1130

Problem Name & Number: WF-22 - Improved methods for presenting and enhancing autoradiographic scan data.

Title Search & RDC Number: Autoradiography 0395

Date Search Initiated: January 22, 1968

Descriptors:

Autoradiography
Radiation Medicine
Tracer
Radiation Detector
Radiation Counter
Radiation Measurement

Date Search Received: January 25, 1968

Number of Hits: 95

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1135

Problem Name & Number: WF-35 - Oxygen Tension in Tissue.

Title Search & RDC Number: Oxygen Tension in Tissue 0395

Date Search Initiated: January 22, 1968

Descriptors:

Oxygen Tension	Spinal Cord	Spine
Sympathetic Nervous System	Synapse	Tissue
	Adipose Tissue	Connective Tissue
Endothelium	Epicardium	Fibrosis
Neuroglia	Oxygen	Oxygen Consumption
Oxygen Metabolism	Nerve	Nervous System
Autonomic Nervous System	Axon	Brain
Central Nervous System	Cerebellum	Cerebral Cortex
Cerebrum	Diencephalon	Ganglion
Myelin	Neuroblast	Neuron
Peripheral Nervous System		

Date Search Received: January 29, 1968

Number of Hits: 273

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1151

Problem Name & Number: NCSU-1 - The Application of Mathematical Modeling Techniques to the Cardiovascular System.
WF-48 - Information on Cardiovascular Systems.

Title Search & RDC Number: Hemodynamic Model 0395

Date Search Initiated: February 19, 1968

Descriptors:

Blood Circulation	Blood Flow	Blood Pressure	Circulatory System
Hemodynamic	Vascular System	Heart	Cardiovascular System
Heart Function	Hemodynamic Response	Heart Rate	Heart Minute Volume
Diastole	Diastolic	Artery	Mathematical Model
Systole	Systolic	Pulsating Flow	Computer Simulation
Unsteady Flow	Analog Simulation	Digital Simulation	Cross Correlation
Dynamic Model	Biological Model	Algorithm	Flow Characteristics
Autocorrelation	Biosimulation	Blood	Frequency Analysis
Closed Cycle	Closed Loop System	Dynamics	Frequency Response
Elastic	Fluid Flow	Pipeflow	Polynomial
Model	Nonlinear	Rheology	Simulation
		Spectral Analysis	Time Series
		Transient Response	Water Hammer Equation

Date Search Received: February 27,1968

Number of Hits: 238

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1162

Problem Name & Number: WF-12 and WF-28*

Title Search & RDC Number: Liquid Flow Measurement 0395

Date Search Initiated: February 12, 1968

Descriptors:

Blood Flow	Blood	Blood Circulation
Cardiovascular System	Vascular System	Vasoconstriction
Vasodilation	Flow Meter	Flow Measurement
Flow Velocity	Mass Flow	Mass Flow Rate
Liquid Flow	Volume	Flow
Rheology	Electromagnetism	Magnetic
Electromagnetic	Thermal	Thermistor
Ultrasonic		

Date Search Received: February 19, 1968

Number of Hits: 550

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

* WF-12 - Variable diameter probe for electromagnetic blood flow meter.
WF-28 - A method of mixing indicator with blood as it is injected into veins and arteries and a method of mixing again just before the sampling site.

COMPUTER EVALUATION REPORT

Biblio. # 1210

Problem Name & Number:

Title Search & RDC Number: Personal Communications Equipment 0395

Date Search Initiated: February 26, 1968

Descriptors:

Communications Device
Radio Receiver
Radio Telemetry
Miniature Electronic Equipment
Microminiaturized Electronic Equipment
Miniaturization
Microminiaturization
Small
Radio Beacon
Radio Transmitter
Superheterodyne Receiver
Personal
Miniature
Subminiaturization
Microelectronics
Biotelemetry

Date Search Received: March 6, 1968

Number of Hits: 76

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1212

Problem Name & Number: WF-39 - Information needed on the physiological effects (radiation damage etc.) arising from use of short-lived radio isotopes in treatment and autoradiography.

Title Search & RDC Number: Short Half-Life Radiation Medicine 0395

Date Search Initiated: February 26, 1968

Descriptors:

Technetium	Indium	Radioactive Isotope
Short	Half-Life	Lifetime
Radiation Dose	Radiation Medicine	Radiobiology
Radiation Therapy	Radiopathology	Oxygen
Partial Pressure	Animal Study	Biological Effect
Physiological Response	Oxygen Tension	Radiation Sickness
Radiation Effect	Radiation Intensity	Radiation Tolerance

Date Search Received: March 4, 1968

Number of Hits: 54

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

COMPUTER EVALUATION REPORT

Biblio. # 1246

Problem Name & Number: WF-43 - Means of Defining Driver Tasks for Automotive Drivers

Title Search & RDC Number: Task Definition 0395

Date Search Initiated: March 8, 1968

Descriptors:

Task
Task Complexity
Job
Element
Step
Definition
Event
Consecutive
Sequence
Sequential Analysis

Date Search Received: 3-14-68

Number of Hits: 48

Date Documents Requested by Researcher:

Number of Documents Requested & List of STAR Numbers:

Degree of Relevance to Problem:

Plans for Use of Information:

APPENDIX B - New Problem Abstracts

BIOMEDICAL PROBLEM ABSTRACTS

UNCD-3

"A Means to Obtain Rapidly a Pictorial Representation of the Temperature Distribution of the Interior of the Oral Cavity in Humans"

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you."

Problem Abstract

UNCD-3
March 18, 1968

Needed

A means to obtain rapidly a pictorial representation of the temperature distribution of the interior of the oral cavity in humans.

Background

Infrared scanning techniques developed to meet U. S. military requirements have been applied to various areas of medicine. In particular thermograms, generated by infrared scanning techniques, have been used to study such varied phenomena as the heat loss from humans in order to design more effective clothing for arctic use. the onset of, gangrene in frostbite injuries, the prediction of the depth of dermal burns, and the relationship between malignancy and tissue metabolism. It has been discovered that the skin temperature is lowered by underlying layers of fat, regions of low metabolic activity such as areas of benign inactive processes, and necrotic and gangrenous tissue. Conversely, pools of rapidly flowing blood, bruises, inflammations, and rapidly dividing malignant cells elevate the skin temperature locally. Using this criteria, thermograms have been useful in differentiating between benign and malignant tumors near the surface of the skin. Thermography has been used with success in diagnosis of diseases of the breast, particularly carcinoma, and experimentation is currently underway by many researchers to apply this technique to other areas of the body. Experiments have been made with currently available equipment in an attempt to diagnose malignancy in the oral cavity.

Requirements

To obtain a thermogram of the interior of the mouth it is, of course, necessary to open the mouth. As soon as the mouth is opened, a thermal gradient is caused by the temperature difference between the outside ambient atmosphere and the internal temperature of the mouth. This causes the interior of the mouth to cool down rapidly, with portions near the mouth opening cooling more rapidly than other areas. In addition it is extremely difficult for the patient to abstain from breathing through the

mouth. In spite of conscious efforts by the patient there is a small influx and efflux of air through the mouth adding a further thermal perturbation. Present scanning equipment requires four minutes to produce a thermogram of the mouth. Because of this long scanning time, the temperature variations due to breathing and the temperature differential between the interior of the mouth and the ambient atmosphere completely mask the original temperature distribution in the oral cavity. Thus, the basic requirement is to drastically reduce the time required to scan the oral cavity. To be useful it is felt that the thermogram must be obtained in 20 seconds, and preferably even quicker. Resolution of the present equipment is $1mm^2$, and its sensitivity is $0.1^{o}C$. These are considered adequate; however, an increase in sensitivity to $0.05^{o}C$ is desirable.

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Chapel Hill, North Carolina

BIOMEDICAL PROBLEM ABSTRACTS

UNCD-6

"A Small Sensor to Measure Accurately the Surface Temperature of Human Teeth"

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you."

Problem Abstract

UNCD-6
March 18, 1968

Needed

A means of determining the condition of individual teeth. One factor that has been considered in determining the condition of teeth is their temperature. The tooth pulp has a characteristic temperature just as the overall body has a characteristic temperature. The temperature of a tooth will deviate from this characteristic value depending on whether the tooth is normal, diseased, or dead. Thus, accurate measurement of the temperature of a tooth will aid clinical diagnosis of the condition of the tooth.

Requirements

Methods of measurement which do not require direct contact (for example, IR detection) create problems if the mouth must be opened to permit the measurements. A thermal gradient is immediately set up between the interior of the mouth and the outside environment. Unless the temperature of all the teeth in the mouth are measured simultaneously and virtually instantaneously, the loss of heat from the mouth will cause nonlinear variations in the temperature of the various teeth as a function of time and tooth location. In addition, breathing through the mouth, which produces further perturbations in tooth temperature, cannot be easily prevented by conscious effort on the part of the patient for periods much greater than 20-30 seconds.

Basically, a temperature sensor for this use should be capable of operation in the range of 80-110^{o}F. Required sensitivity is 0.1^{o}F, and the surface area of active contact should not exceed 1 mm^{2}. In addition, a response time of 10-20 seconds or less is desirable. Since the sensor must be attached to a tooth in the mouth of a patient, the effect of the mouth environment, the attachment method, and the necessity for small size must be considered.

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BIOMEDICAL PROBLEM ABSTRACTS

UNCD-11

"An Improved Bacteria Sampling Technique"

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you."

Problem Abstract

UNCD-11
March 18, 1968

Needed

A means of sampling bacteria in the nasal pharyngeal passage which is simpler and less unpleasant to patients than cotton-wrapped wire swabs.

Background

An investigator at the Dental Research Center at the University of North Carolina Medical School is engaged in a program of sampling bacteria in the upper respiratory tract and the oral cavity of a number of children with and without complete development of the nasal and palatal tissues. These children are available on a regular basis for sampling, and their availability to such a program permits the accumulation of valuable information on the development and growth of bacteria in the respiratory and nasal passages in various conditions of nasal and palatal development. The programs will last for 125 weeks, and on the average six persons per week will be sampled. Samples will be obtained from three areas on each person--the nose, the throat, and the mid-nasal pharynx. From these samples, cultures are grown, and bacteria present are identified and quantified.

Present technique

The sampling technique now being employed is the following. A speculum is used to permit entry into the nasopharynx through the nose. A small wire, usually aluminum, which has a ball of alginate wool on the end, is passed through the speculum and into the nasal cavity. The ball of wool is made to come into contact with the tissue floor in the nasopharyngeal passage, thus collecting the bacteria. The swab is then removed, and the entire swab is dissolved in solution. The swab presently used is a commercial item called Calgiswab. It is a calcium alginate swab manufactured by Consolidated Laboratories, Incorporated, of Chicago Heights, Illinois. The calcium alginate wool which is used to pick up the bacteria is non-toxic and is soluble in sodium salts such as citrate. The solubility of the wool permits one to dissolve the swab in solution and to recover the entire bacteria sample. Other types of non-soluble swabs, for example

cotton, have not been as satisfactory because much of the bacteria are retained by the swab and cannot be removed. After the bacteria sample is taken and the swab dissolved, the solution is ultrasonically vibrated to mix and to deflocculate the bacteria. Next, the sample undergoes a standardized dilution technique, and specific quantities of the fluid are placed on Petri plates containing selective agar media to grow cultures. Counting of bacteria colonies is done using manual techniques with a dissecting microscope. Identification of bacterial types is likewise accomplished manually.

The sampling procedure is not liked by the patients because of its discomfort. The nasal passages are extremely sensitive, and the insertion of the swab is irritating and uncomfortable. This problem of discomfort is heightened by the fact that the patients being sampled are children, and they must be sampled repeatedly to determine variations in the bacteria related to upper respiratory infections and changes produced by their therapy.

Initial requirements

The basic requirement in this problem is the necessity to reduce the amount of discomfort experienced by the children during the sampling operation and yet, at the same time, provide a reliable means of sampling the bacteria present in the nasal cavity, the throat, and the midnasal pharynx. It has been observed that unless these three areas are sampled, or at least the throat and the nasopharynx, important respiratory bacteria can go undetected. It is specifically hoped that the Aerospace Medical Program may have lead to the development of such a sampling technique and the requisite proof of feasibility of the technique.

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BIOMEDICAL PROBLEM ABSTRACTS

UNCD-12

"A Method of Measuring Subglottal Pressure"

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you."

Problem Abstract

UNCD-12
March 18, 1968

Needed

A method of measuring air pressure in the subglottal region.

Background

An investigator at the University of North Carolina Dental Research Center is studying the effects of varying degrees of cleft palate defects in children and also the effects of corrective surgery in restoring the speech function of these children. It has not been possible to correlate the degree of speech intelligibility with the amount of palate damage in a clear manner. To provide more definitive characterization than the relatively qualitative judgement of speech intelligibility, the investigator has begun to characterize some of the basic parameters involved in speech. Pressure and volume measurements in the nasal and oral cavities have been instrumented. Another such parameter in children having these defects is the ability of the child to generate a pressure in the subglottal region. The measurement of subglottal pressure, however, is not an easy task because of the relative discomfort associated with such measurements using conventional techniques.

There are basically two conventional techniques. The first involves the use of an esophageal balloon which is inserted below the glottis into the esophagus and inflated. This device permits measurement of the pressure created in the subglottal region. Unfortunately, its accuracy depends upon factors such as the volume and capacity of the lungs, and each person must be separately calibrated in order to obtain meaningful measurements from this device. Even when calibrated, there is some uncertainty about the accuracy of the measurements. The presence of the balloon is a problem in that it causes the patients to gag, and in itself produces an undetermined effect on the measurement which is being made. The use of the balloon is very distasteful to children, and it is difficult to use in routine measurements. The other method involves the insertion, from the outside, of a hypodermic needle through the trachea into the subglottal region. With this method, a pressure transducer is attached to

the hypodermic needle on the outside. This procedure is not often used for several reasons. The foremost reason is that few people will submit to having a hypodermic needle stuck into their throat; children particularly are adverse to this sort of treatment. Second, in order to penetrate this region the hypodermic needle must be rather small. This introduces frequency response limitations such that the pressure output indicated by the transducer is not very useful for making dynamic measurements. The pressure to be measured in the subglottal region is in the range of 0 to 8 cm of water pressure.

Specifications

The pressure transducer or measuring system must possess the following characteristics:

1. Any invasive technique must employ devices sufficiently small that undue discomfort will not be caused in children (<0.5 mm in diameter).
2. The anticipated pressure range is from 0 to 8 cm of water pressure.
3. Five percent accuracy is desirable.
4. The temperature sensitivity should be small. This is true because the air passing from the lungs to the outside and from the outside to the lungs differs in temperature by several degrees, with a continual oscillation as a person inhales and exhales, so that a high temperature sensitivity in the measuring technique would render the technique useless.
5. While not a primary factor, cost should be considered in any suggestion involving development of a measuring system.

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BIOMEDICAL PROBLEM ABSTRACTS

WF-29

"An Electrode for Measuring Hydrogen Ion Concentration and Carbon Dioxide Partial Pressure in the Blood"

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C.

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you."

Problem Abstract

WF-29
October 1967

Needed

An electrode for measuring hydrogen ion concentration and carbon dioxide partial pressure in the blood. The response time of the electrode should be 30 seconds or less. Currently available devices have a response time which varies from 90 seconds to 2 minutes.

Background

Investigators at the Bowman Gray School of Medicine, Wake Forest University are interested in making continuous measurement of the carbon dioxide content of blood outflowing from the brain or in the brain tissue. The response of certain areas of the brain to stimuli are considered to be related to the carbon dioxide partial pressure in the blood. These carbon dioxide pressure variations in the blood are thought to occur in less than 30 seconds while the response time of the commercially available electrodes is of the order of 2 minutes. The presently available carbon dioxide electrode unit is a pH glass electrode that is arranged to measure the pH of a very thin film of aqueous sodium bicarbonate solution which is separated from the sample by a teflon membrane that is permeable to carbon dioxide gas molecules but not to ions that might alter the pH of the carbonate solution. The aqueous bicarbonate layer is maintained between the glass electrode and the teflon membrane by a matrix consisting of very thin cellophane or a fine nylon mesh. This layer is kept saturated by the reservoir of bicarbonate solution in the lucite jacket. It also acts as a liquid salt junction between the measuring tip of the glass electrode and the reference electrode.

When carbon dioxide molecules diffuse through the teflon membrane, they dissolve into the aqueous bicarbonate layer. The carbon dioxide reacts with water giving carbonic acid, thus lowering the pH. The pH falls nearly one pH unit for 10-fold increase in the partial pressure of carbon dioxide. Hence, pH is a linear function of the logarithm of the partial pressure of carbon dioxide. The electrode measures this change in potential which is converted to millimeters of mercury partial pressure of carbon dioxide. The thickness of the aqueous bicarbonate layer and the reaction time required are such that the response time of this particular electrode is excessive (approximately 2 minutes). To monitor the rapid changes in partial pressure of

carbon dioxide in the blood in the brain resulting from stimuli, it is necessary that an electrode or other device for measuring the partial pressure of carbon dioxide in the blood be obtained which has a response time of less than 30 seconds.

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BIOMEDICAL PROBLEM ABSTRACTS

WF-30

"An Improved Blood Vessel Constrictor"

Prepared for

National Aeronautics and Space Administration
Technology Utilization Division
Washington, D. C. 20546

"This problem abstract is designed to call to the attention of NASA personnel (and others who have agreed to participate) significant barriers that impede the progress of biomedical research and health care. The purpose is to bring to bear on these problems the expertise that resides in NASA. If you feel you can make a contribution, please communicate your suggestions to the Technology Utilization Officer at your installation. Also, alert him to any suggestions which can constitute inventions so that patent application may be made. Thank you."

Problem Abstract

WF-30
January, 1968

Needed

An improved blood vessel constrictor applicable to open surgery. The constrictor must be capable of controlled constriction of blood vessels and instant release.

Background

In cardiac and vascular studies at the Bowman Gray School of Medicine, Wake Forest University, investigators frequently need some device that can be placed around a blood vessel during open surgery to cause a controlled stricture of the vessel. Currently used devices possess several disadvantages. First, these devices are relatively difficult to use and awkward to handle. Second, and more important, the devices are difficult to release rapidly. It is important that the constriction on the blood vessel be removed rapidly because experiments frequently require that the blood flow be reduced to the point that the test animal will die unless immediate release of the constrictor can be accomplished. These test animals are carefully controlled and instrumented, and their histories are well-known. Loss of such an animal represents a significant loss of time and money. Consequently, instant release of the constriction is of great importance.

Requirements

The basic requirements which such a blood vessel constrictor should meet are outlined below. The constrictor must be able to apply a known and controllable amount of constriction to the blood vessel. The ability to release the constrictor instantly is considered of prime importance. The manner in which the constriction is applied to the blood vessel must be such that the constrictor itself does not cut into the blood vessel as constriction is applied. This requirement must be met even to the point where the blood vessel is completely closed. The amount of space available for the constrictor is limited. Specifically, the length of blood vessel exposed is generally no more than 1½ inch and usually on the order of one

inch. This necessitates small size and a simple method of attachment to the blood vessel.

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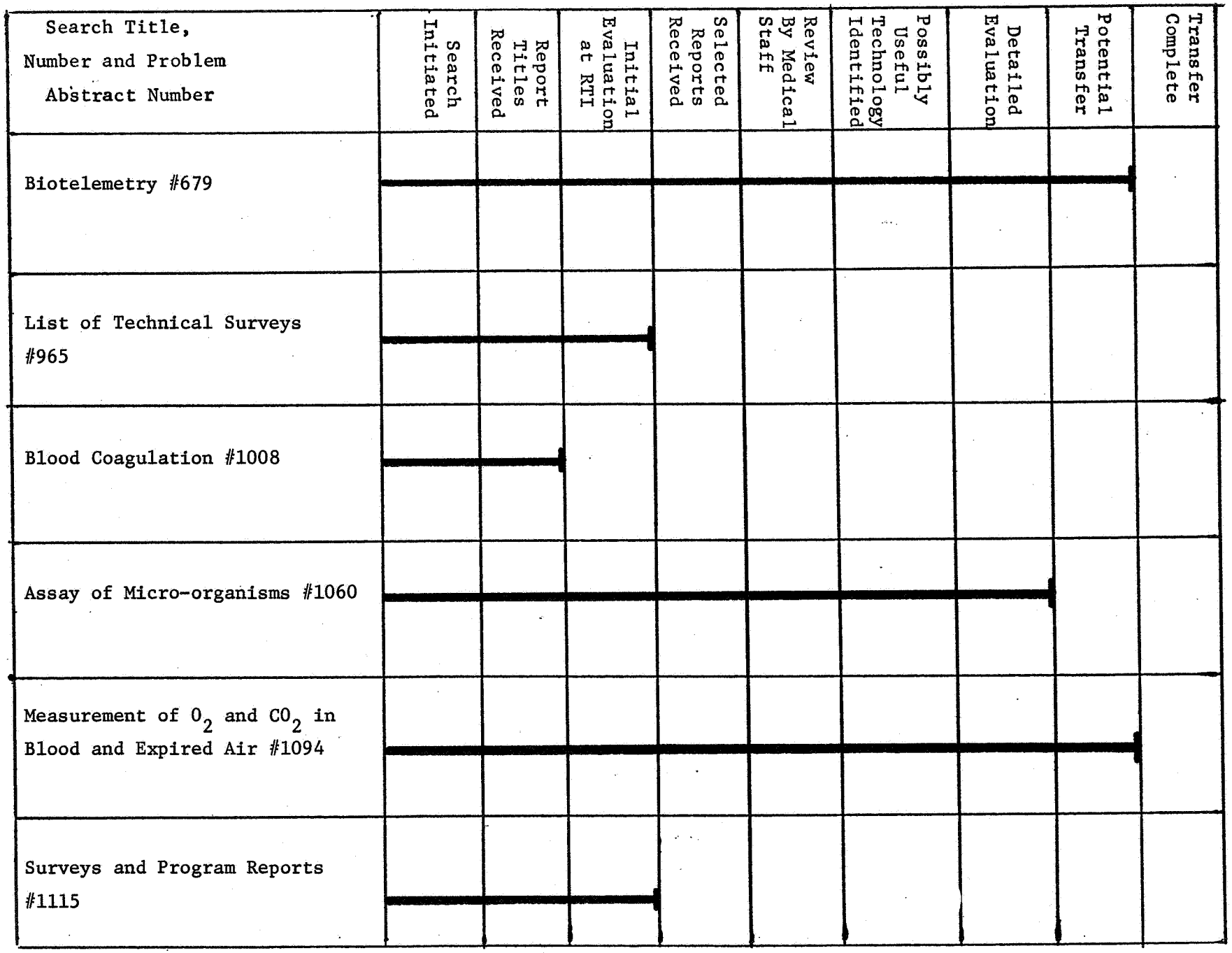
FOREWORD

The information search status charts herein contain status information on active searches during the quarter. Searches on which no further action has been taken since the last report are not included.


Search Title, Number and Problem Abstract Number
Search Initiated
Report Titles Received
Initial Evaluation at RTI
Selected Reports Received
Review By Medical Staff
Possibly Useful Technology Identified
Detailed Evaluation
Potential Transfer
Transfer Complete
Biotelemetry #679
List of Technical Surveys #965
Blood Coagulation #1008
Assay of Micro-organisms #1060
Measurement of 0_2 and CO_2 in Blood and Expired Air #1094
Surveys and Program Reports #1115

Search Title, Number and Problem Abstract Number	Search Initiated	Report Titles Received	Initial Evaluation at RTI	Selected Reports Received	Review By Medical Staff	Possibly Useful Technology Identified	Detailed Evaluation	Potential Transfer	Transfer Complete
Blood Flow Meters #1128									
Autoradiography #1130									
Oxygen Tension in Tissue #1135									
Hemodynamic Model #1151									
Liquid Flow Measurement #1162									
Short Half-Life Radiation Medicine #1212									

Transfer Complete						
Potential Transfer						
Detailed Evaluation						
Possibly Useful Technology Identified						
Review By Medical Staff						
Selected Reports Received						
Initial Evaluation at RTI						
Report Titles Received						
Search Initiated						
Search Title, Number and Problem Abstract Number	Task Definition #1246					

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